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STRATIGRAPHY AND PLANKTONIC FORAMINIFERA OF THE UPPER CRETACEOUS–LOWER TERTIARY SUCCESSION IN THE ESNA–IDFU REGION, NILE VALLEY, EGYPT, U.A.R.

BY

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STRATIGRAPHY AND PLANKTONIC FORAMINIFERA OF THE UPPER CRETACEOUS–LOWER TERTIARY SUCCESSION IN THE ESNA–IDFU REGION, NILE VALLEY, EGYPT, U.A.R.

By Z. R. EL-NAGGAR

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SYNOPSIS

The Upper Cretaceous–Lower Tertiary succession of the Esna–Idfu region is examined in detail, and the macrofauna as well as the planktonic Foraminifera are used to interpret the stratigraphy of the region. A total of 119 species and subspecies of planktonic Foraminifera are described, 20 species and 6 subspecies of which are new; 142 macrofossil species are also identified and their ranges given. The succession is divided into distinct litho- and bio-stratigraphical units, most of which are new. The position of the Campanian–Maestrichtian boundary is suggested, and the Maestrichtian is defined and zoned. It is considered as the uppermost stage of the Cretaceous system while the Danian is regarded as the lowermost stage of the Tertiary. The Cretaceous–Tertiary boundary is proved to be marked by a distinct break, despite previous emphasis on the absolute conformity of the succession. Strata of Danian age, with the typical planktonic Foraminifera of the type section have been discovered, and have proved that previously recorded Danian strata in Egypt were incorrectly dated. The controversy over Paleocene stratigraphy is discussed in detail, and it is recommended that the use of the existing stage names (other than Danian) be avoided until their chronological relationships are clarified. A threefold division of the Paleocene on the basis of its planktonic Foraminifera is proposed, and the position of the Paleocene–Lower Eocene boundary is suggested.

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II. INTRODUCTION

Since the later part of the nineteenth century the highly fossiliferous Upper Cretaceous and Lower Tertiary rocks of Egypt have been the subject of numerous stratigraphical and palaeontological studies. However, no satisfactory classification of these rocks was established and their correlation with the type sections in Europe proved very difficult. The difficulty has been mainly explained by the fact that the rich macrofaunas of these rocks are strictly localized in nature, and can hardly be correlated with the faunas of corresponding strata outside the Tethyan region. As a result, the limits of the various stages and substages of the Upper Cretaceous and Lower Tertiary were differently interpreted by the various authors, and were chosen, as stated by Youssef (1957 : 45), " rather arbitrarily, on whatever meagre evidence the stratigrapher can collect ".

Recently, the rich microfossil content of these rocks has been dealt with by many authors, but correlation with the type sections still proved very difficult, and the stratigraphical boundaries were, once again, differently interpreted. Moreover, the discrepancies between zonations based on macrofossils and those based on microfossils led to further complications, and regrettably no attempt was made to treat together the co-existent macro- and micro-faunas. This, added to the world-wide problems of Cretaceous–Tertiary stratigraphy, has resulted in the complication of the stratigraphical interpretation of this period in Egypt.

The same problems were faced in trying to analyse the stratigraphy of the Upper Cretaceous–Lower Tertiary succession of the Esna–Idfu region. However, the accumulation of knowledge during the last twenty-five years has emphasized the value of planktonic Foraminifera as guide fossils for stratigraphical zonation, and for regional as well as world-wide correlation. In this connection, Loeblich & Tappan (1957*b* : 1109) stated that " Because of their independence of the sea bottom, rapid dispersal by ocean currents, and their ability to select the depth and therefore to some extent the temperature they prefer while living, their relatively rapid evolutionary development, and their buoyancy which allows further current dispersal even after death of the organism, certain planktonic forms supply the best available evidence for world-wide correlations ". Thus, in the present study both the macrofauna and the co-existent planktonic Foraminifera are identified and are used to interpret the stratigraphy of the region. While the macro-fossils were found to be restricted in their geographical distribution and only useful for local correlation, the planktonic Foraminifera provided a sound basis for the zonation of the succession and its correlation with the type sections and with the known planktonic foraminiferal zones elsewhere. Moreover, the stratigraphical ranges of the macrofossils could be established in the light of the planktonic foraminiferal zonation, thus ending a long controversy about their ranges.

However, despite the remarkable value of planktonic Foraminifera, the stratigraphical and taxonomic confusion surrounding many of the species, has almost masked their importance. The rich planktonic foraminiferal populations encountered in the Upper Cretaceous–Lower Tertiary succession of the Esna–Idfu region have helped to clear up this confusion and to establish the morphological characteristics and the stratigraphical range of each of these species. This wealth of planktonic Foraminifera, which probably marks the succession as the richest ever recorded, provided an excellent opportunity for a detailed study of inter- and intraspecific variation among large species populations and for a study of the phylogenetic relationships between the various forms recorded. The main part of this work is therefore devoted to a detailed study of the important members of the planktonic Foraminifera, many of which are here described for the first time from Egypt, North Africa and the Middle East.

LOCATION AND GEOLOGICAL SETTING OF THE ESNA–IDFU REGION. This region lies in Upper Egypt between latitudes 24°58′00″ N and 25° 20′00″N, and longitudes 32° 20′00″ E and 33° 05′00″ E. It includes part of the Nile Valley between the towns of Esna and Idfu, and extends eastwards and westwards into the vast deserts on either side, covering an area of about 3,200 square kilometres (Text-fig. 1).

The region is bounded on the west and northwest by the Lower Eocoene limestone scarp (El-Sinn) which forms the eastern edge of the famous limestone plateau of the Western Desert. On the south and east, it is bounded by the Nubia sandstone plateau, which extends in both directions outside the region to the basement complex, at a distance of about 75 kms. to the east and about 100 kms. to the south.

This Nubia sandstone plateau extends into the Esna–Idfu region constituting most of its eastern, southeastern and southern parts, dipping gently to the northwest to be progressively overlain by the Sibaîya phosphate, the Esna shale and finally by the Thebes limestone and calcareous shale. These four main lithological units, which are clearly recognizable in the field, together constitute the Upper Cretaceous–Lower Tertiary succession of the Esna–Idfu region. They form the main part of the outcrops in the region and are locally unconformably overlain by one or more of the much younger deposits of the Pliocene, Pleistocene and Recent, which constitute the rest of the outcrops in the region (Text-fig. 3).

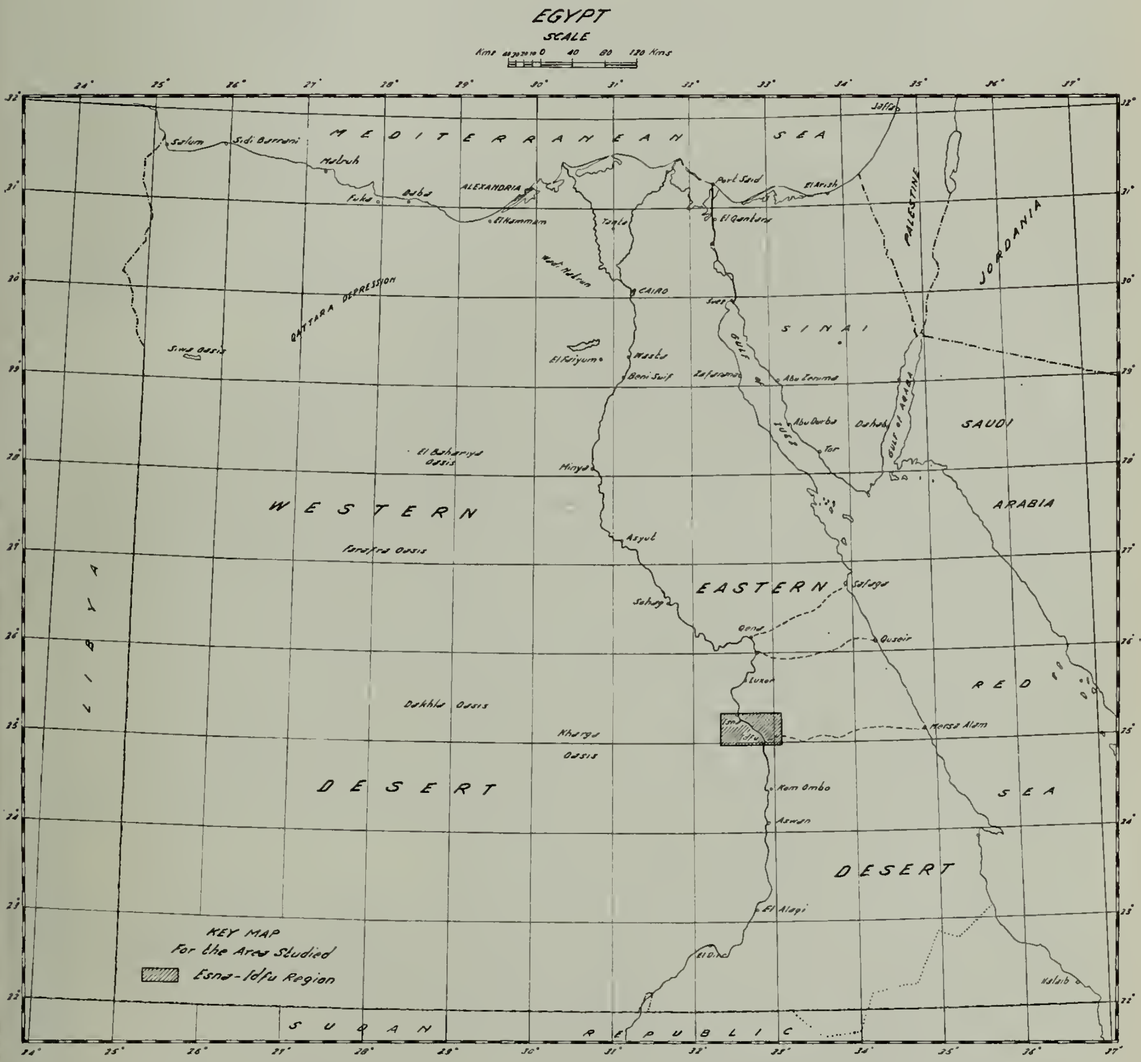

FIG. 1. Map of Egypt.

Previous work. The Esna–Idfu region has attracted the attention of geologists since the earliest days of geological reconnaissance in Egypt, for the following reasons :

1. It is the only locality in the Nile Valley where both the uppermost Cretaceous and the basal Tertiary rocks are very well developed and well exposed.
2. It is the type area of the famous " Esna shale ", an important group of rock units which cover vast areas of the surface and subsurface of Egypt, representing a relatively long period of time.
3. It contains the economically important phosphate deposits of the " Sibaîya formation ".

In spite of its geological importance, little has been published about the Esna–Idfu region, and most publications deal mainly with the phosphate deposits. However, the stratigraphical succession at a few outcrops in the region was described in general terms by Zittel (1883), Schweinfurth (1901, 1904), Beadnell (1905), Hume (1911), Stromer & Weiler (1930), Cuvillier (1937*a*, *b*), Nakkady (1951*b*) and Youssef (1954), but no detailed study has ever been attempted.

After examining the Upper Cretaceous–Lower Tertiary succession of the Western Desert Oases, which he collectively related to the Danian, and divided into lower *Exogrya overwegi* beds, middle greenish and ashen-grey paper-like shales, and upper chalk with *Ananchytes ovata*, Zittel (1883) extended his study to the Nile Valley. He pointed to the importance of the conspicuously developed oyster limestone bed near Idfu which he wrongly regarded as equivalent to the " *Exogyra overwegi* beds " of the Kharga Oasis. He also observed the great thickness of Esna shale underlying the Lower Eocene " *Operculina* limestone " on the right bank of the Nile near Esna, and added " If these paper-shales of Esneh correspond with those of Khargeh and Dakhel, then the uppermost white Cretaceous limestone with *Ananchytes ovata* is either wanting at Esneh, or does not contain any fossils and cannot thus be distinguished from the petrographically similar Eocene limestone of the Libyan stage. " Apparently, Zittel wrongly correlated the shales directly underlying the Lower Eocene limestone near Esna with the lower shales underlying the snow-white chalk of the Oases. However, as far as is known to the writer, this is the first record of the " Esna shale " in the geological literature of Egypt.

Schweinfurth (1901, 1904) also recorded these paper shales on both banks of the Nile at Esna and El-Sharawna, and considered them to be of Eocene age following the general belief of his time. However, neither Zittel (1883) nor Schweinfurth (1901, 1904) observed any fossils in these shales.

Beadnell (1905), in a reconnaissance study designed to explain the mutual relationship of the Cretaceous and Eocene systems (as understood by him), described the succession in the desert margins on both sides of the Nile Valley between Aswan and Esna in a series of disconnected sections. He briefly described two sections within the Esna–Idfu region, the first was measured in the hills about one kilometre northeast of Idfu railway station, near the village of El-Atwani, where a succession of

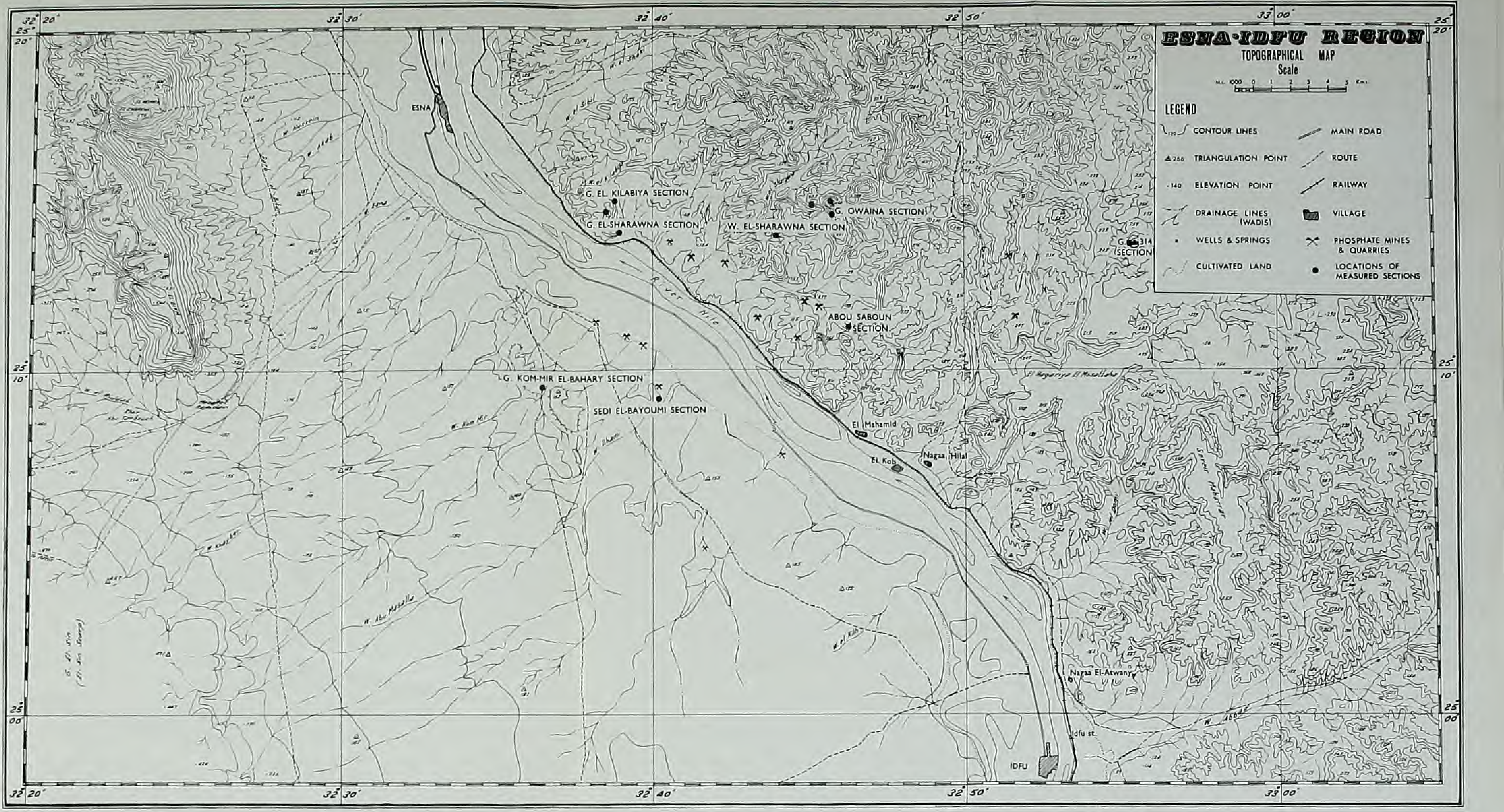

FIG. 2. Esna-Idfu Region. Topographical Map.

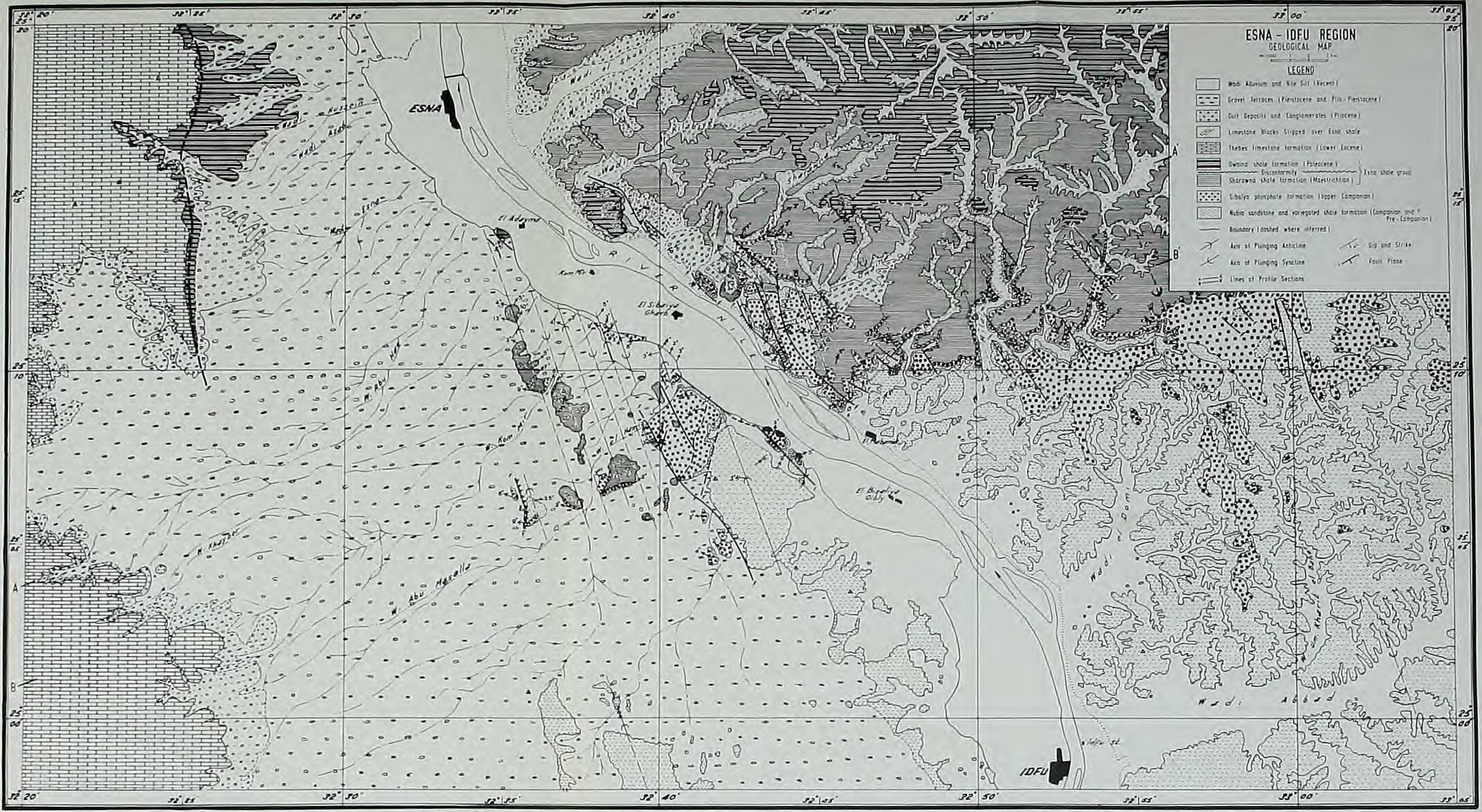
ESNA - IDFU REGION
GEOLOGICAL MAP
LEGEND
Wadi Alluvium and Nile Silt (Recent)
Gravel Terraces (Pleistocene and Plio-Pleistocene)
Gulf Deposits and Conglomerates (Pliocene)
Limestone Blocks Slipped over Esna shale
Thebes limestone formation (Lower Eocene)
Owaina shale formation (Paleocene)
Disconformity
Sharawna shale formation (Maestrichtian)
Esna shale group
Sibaiya phosphate formation (Upper Campanian)
Nubia sandstone and variegated shale formation (Campanian and ? Pre-Campanian)
Boundary (dashed where inferred)
Axis of Plunging Anticline
Axis of Plunging Syncline
Dip and Strike
Fault Plane
Lines of Profile Sections
ESNA
IDFU
El Adaima
Kom Mir
El Sibaiya Gharb
El Basaliya Qibli
RIVER NILE
Idfu St.
Wadi Abbad
W. Abu Masalla
A
B
A'
B'
32° 20'
32° 25'
32° 30'
32° 35'
32° 40'
32° 45'
32° 50'
32° 55'
33° 00'
33° 05'
25° 20'
25° 15'
25° 10'
25° 05'
25° 00'

FIG. 3. Esna-Idfu Region. Geological Map.

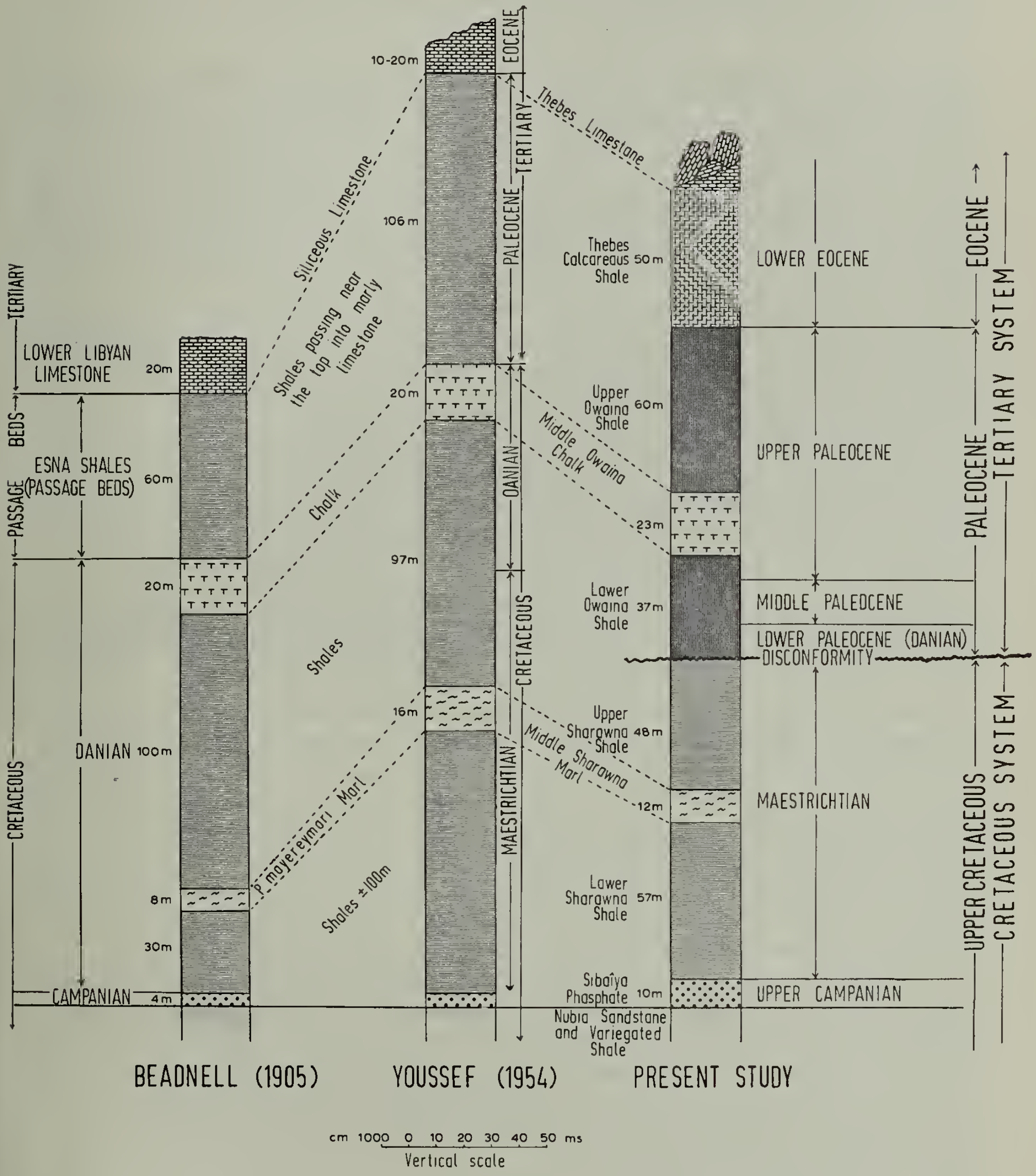

FIG. 4. Correlation of the stratigraphical succession in G. Owaina section as interpreted by Beadnell (1905), Youssef (1954) and by the present study.

Nubia sandstone and variegated shale, 112 metres thick, is capped by oyster limestone. The second was the famous Gebel Owaina section, which was later described in more detail by Youssef (1954).

Both Beadnell (1905) and Youssef (1954) considered the succession in Gebel Owaina to be conformable throughout. Beadnell stated that " . . . . . the first fact that impresses the observer is the absolute conformity of the succession throughout.", and Youssef also stated " The sequence is apparently conformable throughout."

The descriptions of the succession and the interpretations of the stratigraphy given by Beadnell (1905) and by Youssef (1954) are summarized and compared with those of the present study in Text-fig. 4.

Hume (1911) briefly described the succession in the shallow valleys to the east of El-Kilabiya village. He considered the strata between the Campanian oyster limestone and the Lower Eocene nummulitic limestone as belonging to the Danian, which he regarded as the uppermost Cretaceous.

Stromer & Weiler (1930) described the vertebrate remains of both the Nubia formation and the overlying phosphate beds of the Mahamid district, and the geology of the same district was briefly dealt with by Nakkady (1951*b*). In agreement with previous works, these authors confirmed the Campanian age of both the Nubia and the phosphate formations.

Cuvillier (1937*a,b*) in a very generalized discussion, assigned the shale and the intervening chalk succession of both Gebel El-Kilabiya and Gebel El-Sharawna to what he collectively described as Maestrichtian–Danian.

Youssef (1954) described the succession in the Gebel Owaina section, using the Foraminifera as well as the macrofossils to interpret the stratigraphy. Although he overlooked the distinct break between the Cretaceous and Tertiary rocks and considered the Danian (within which he included most of the Paleocene) as the youngest stage of the Cretaceous system, his study is the only serious attempt to tackle the stratigraphical problems of this section. Youssef did not deal with the Nubia sandstone and the phosphate beds which constitute the lowest part of the succession, but simply noted that Beadnell (1905) assigned a Campanian age to the latter beds. However, he referred the shale section directly overlying the phosphate beds to the Maestrichtian, and arbitrarily considered the Maestrichtian–Danian boundary to cut through the middle part of his 97 metres thick shale succession overlying the *Pecten mayereymari* marl (see Text-fig. 4). He assigned the upper half of this shale section and the overlying chalk bed to the Danian, and referred the upper shale section to the Paleocene and the overlying siliceous limestones to the Lower Eocene, although he added that a closer study may prove that these limestones are still of Paleocene age.

Youssef (1954), following Cuvillier (1934) and Nakkady (1951*a*) suggested that the term Esna shale, as a formation name, should be abandoned to avoid the different age significances adhering to the term through long use. However, he added that the

" Esna shales ", as a facies name, should be retained and thus proposed the term " Esna shale facies ", " . . . . . as an expression of certain lithological and palaeontological characters of a part of the stratigraphic column in certain parts of Egypt."

In all these studies the succession was only briefly described, and the limits of the various stages and substages were vaguely defined. As a result the succession was wrongly considered to be conformable throughout, and correlation with the type sections or the known other sections outside the Tethyan region could not be achieved. Moreover, no palaeontological study was ever attempted and no geological map of the region was published, except for a very small part in the neighbourhood of El-Kab which was mapped by Schweinfurth (1904). The latter has only schematically shown the distribution of what he described as Campanian, scattered, rolled Eocene pebbles, and Pleistocene and Recent. A part of this map was used by Nakkady (1951*a*) where the same mapping units were followed.

In a recent geological study of the Esna–Idfu region, the present writer mapped the area in detail. This mapping which has resulted in the classification of the surface rocks into distinct litho- and bio-stratigraphical units, has also proved for the first time, the existence of a distinct break between the Maestrichtian and the overlying Paleocene rocks. In spite of repeated emphasis on the absolute conformity of the succession by previous workers, a conglomerate with reworked Upper Cretaceous macrofossils was clearly observed in the field and a distinct faunal break was proved by the study of the macrofauna and the planktonic Foraminifera. The existence of such a stratigraphical break in a region where continuous deposition and absolute conformity between the Cretaceous and Tertiary systems has been unquestionably accepted, throws a new light on the geological history of Egypt during late Cretaceous and early Tertiary time. Moreover, comparison with various Upper Cretaceous–Lower Tertiary sections in Egypt has clearly indicated the existence of stratigraphical breaks of varying magnitudes in areas where the succession was described as conformable throughout.

The detailed geology of the region is discussed elsewhere (El-Naggar, *in manu.*) and the main objects of the present investigation can be summarized as follows :

1. Stratigraphical analysis of the Upper Cretaceous–Lower Tertiary succession of the Esna–Idfu region on the basis of its lithology and macrofossil content, and correlation with corresponding sections in other parts of Egypt.
2. Analysis of the succession on the basis of its planktonic Foraminifera ; correlation with the planktonic foraminiferal zones in other parts of the world, and the establishment of the ranges of the recorded macrofossil species in the light of the planktonic foraminiferal zonation.
3. Detailed systematic study of the planktonic Foraminifera.

METHODS OF INVESTIGATION. The Esna–Idfu region was geologically mapped, using topographical sheets, scale 1 : 100,000 and aerial photographs, scale 1 : 40,000. As stated above, the detailed geology of the region and the maps are discussed elsewhere and only small scale reproductions of the maps are presented here (Text-figs. 2,

3) to show the distribution of the various rock units and the location of the sections studied.

Every possible outcrop in the region was carefully examined and sampled ; fossils were collected, and lateral as well as vertical variation in the different rock units was considered. The succession was first divided, on the basis of its lithology, into five formations and eight members (Text-fig. 5) which are clearly distinguished in the field. It was then zoned on the basis of the macrofossils in its various units, and was correlated with similar successions in other parts of Egypt. However, because of the restricted geographical distribution of most of these macrofossils, correlation with the type sections or the other known sections outside the Tethyan region could not be achieved, and thus the limits of the various stages and substages could not be definitely decided.

To overcome this difficulty, eight main sections, representing the succession in different parts of the region (Text-fig. 7) were chosen for the detailed study of planktonic Foraminifera. Several other sections were also examined, but being mainly composed of the Nubia sandstone and/or the Sibaîya phosphate formations, they were either devoid of Foraminifera, or yielded only very rare, indeterminable specimens and are not discussed here.

The sections were measured and sampled in detail, using a tape, a Brunton compass and an " Abney-level ". Samples were collected every three metres and every metre or even fraction of a metre when necessary (Text-fig. 7).

About three hundred samples (100 gms. of each) were processed for foraminiferal analysis using standard techniques which differed according to the nature of the rocks. In each case, the residue was dried and passed through a series of sieves (30, 60, 120 and 200 mesh).

All the planktonic Foraminifera in each fraction were picked out and examined, counts were made and range charts were constructed. However, as the ranges were found to conform well in all the studied sections, it was not found necessary to present a chart for each section. The ranges on the general charts, here included, represent the ranges in the corresponding parts of each of the studied sections.

Ninety five species and twenty four subspecies of planktonic Foraminifera are identified, twenty species and six subspecies of which are new. All members of the genera *Globotruncana*, *Globigerina* and *Globorotalia* are described and figured, except for a few rare forms which are not figured. All figures are camera lucida drawings by the author. Members of the genera *Abathomphalus*, *Rugoglobigerina*, *Trinitella* and *Hedbergella* are only listed and will be figured and described in a future publication.

Comparison with type material was carried out wherever possible, and in such cases it is noted in the remarks on each species.

All types and figured specimens are in the British Museum (Natural History), London ; a duplicate collection is deposited in the Department of Geology, U.C.W., Aberystwyth.

III. STRATIGRAPHY

A. General Discussion

The controversy about Upper Cretaceous–Lower Tertiary stratigraphy has probably been one of the most prolonged in the history of geological literature. The loose definition of the various stages and substages and their varied interpretation by different authors has always made it difficult to establish the true stratigraphical relationship between one stage and another, and has led to great confusion.

A detailed study of the type sections of these stages and substages, with a critical analysis of previous literature, is very badly needed to clear up this confusion. However, such detail is beyond the scope of the present work, although the author has sampled these sections, and the samples as well as the previous literature are now being analysed. Nevertheless, it was found necessary to summarise the stratigraphical problems of the various stages and substages dealt with here, and the classification adopted in the present study, before proceeding to discuss the succession in the Esna–Idfu region.

The present study is mainly concerned with the period from the Upper Campanian to the Lower Eocene, and the main points of disagreement about the stratigraphy of this period can be summarized as follows :

1. Where should the Campanian–Maestrichtian boundary be drawn, and what is the position of the Maestrichtian in Upper Cretaceous stratigraphy?
2. Does the Danian represent the uppermost Cretaceous or the basal Tertiary, and what is the nature of the Mesozoic–Cainozoic boundary?
3. What is the stratigraphical position of the Paleocene, and the relationship between its various stages and substages?
4. Where should the Paleocene–Lower Eocene boundary be drawn?

The Campanian–Maestrichtian Boundary and the position of the Maestrichtian in Upper Cretaceous Stratigraphy

In 1842, d'Orbigny introduced the term " Senonian " in Upper Cretaceous stratigraphy to define the geological interval represented by the white chalk around " Sens ", southeast of Paris. However, he did not designate a particular type section for his Senonian, but simply stated that " Sens " is situated amidst this white chalk which is characterized by its fauna.

Four years later, Desor (1846) introduced the term " Danian " to describe the succession of the *Cerithium*, bryozoan, coralline and coccolithic limestones which disconformably overlie the Senonian white chalk of Denmark and which he had previously observed at " Laversines " and " Vigny " in the Paris Basin. He considered the Danian as the youngest stage of the Cretaceou system, and the same concept was automatically followed by most stratigraphers.

In 1849, Dumont introduced the term " Maestrichtian " to describe the " calcaire grossier " exploited at the quarries of Maestricht[1] in southern Limbourg, Holland, which he wrongly equated with the " Tuffeau de Ciply " and the limestone of " Folx-les-Caves " in Belgium, and correlated with the " calcaire pisolithique " of the Paris Basin, which Desor had previously correlated with his Danian.

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[1] Dumont's original French spelling of Maestricht is used throughout this work.

A year later, d'Orbigny (1850) described the characteristic fauna of his Senonian, including the Maestrichtian of Dumont as the upper part of this stage.

D'Orbigny (1852) recognised seven stages in the Cretaceous system, all of which except the first and last, were established by him. They are, from the base upwards : Neocomian, Aptian, Albian, Cenomanian, Turonian, Senonian, and Danian. These stages have since been generally accepted by most stratigraphers, in spite of disagreements and controversies regarding their limits.

While d'Orbigny regarded the Senonian as comprising the succession of strata between the uppermost Turonian and the basal Danian, Hébert (1875) excluded the Maestrichtian of Dumont, considering it to range into the Danian, and Haug (1908–11) included the Danian of Desor within the Senonian.

Coquand (1857) divided the Senonian into four substages which he named from the base upwards : Coniacian, Santonian, Campanian and Dordonian. However, de Grossouvre (1897, 1901) considered the Dordonian to be a junior synonym of the Maestrichtian of Dumont (1849) and included the latter within the Campanian as its uppermost part. He also subdivided the Campanian (in his sense), on the basis of ammonities, into four successive zones which he named from the base upwards : the *Placenticeras bidorsatum* Zone, the *Taxanites delawarense* Zone, the *Hoplitoplacenticeras vari* Zone and the *Pachydiscus neubergicus* Zone. On the other hand, Arnaud (1897) showed that the ammonite fauna of the type Dordonian (the *Pachydiscus neubergicus* Zone of de Grossouvre) is quite distinct from that of the Campanian, and should be considered separately. However, in agreement with de Grossouvre, he regarded the Dordonian as a junior synonym of the Maestrichtian thus considering the Senonian stage to include the four substages : Coniacian, Santonian, Campanian and Maestrichtian. This classification was followed by most authors, although the limits between the various substages, especially those of the Campanian and the Maestrichtian, have been largely disputed and mostly unsettled. This has been mainly explained by the fact that the original definition of the Maestrichtian by Dumont (1849) was rather vague and ambiguous and thus its lower limit has been always chosen arbitrarily by the different authors. Again, while in fact no definite Maestrichtian deposits have yet been described in the Paris Basin, Dumont wrongly correlated the Maestricht chalk tuff with the so-called " pisolitic limestone " of Laversines and Vigny, which further complicated the problem. Moreover, de Grossouvre (1897, 1901) on the one hand, included the Maestrichtian within the Campanian as its uppermost part, and Haug (1908, 1911) on the other, extended the Maestrichtian downwards in the succession to include the uppermost part of the Campanian at its base. As a result, Haug attached the chalk with *Belemnitella mucronata* to the Maestrichtian, and thus considered the Meudon Chalk of the Paris Basin, and the " chalk of d'Obourg ", the " Nouvelles chalk ", the " Spiennes chalk " and the " phosphatic chalk of Ciply ", in Belgium to be of Maestrichtian age. To justify this, he subdivided the Upper Campanian *Hoplitoplacenticeras vari* Zone of de Grossouvre into a lower zone with *Hoplitoplacenticeras vari* which he considered to be of Upper Campanian age, and an upper zone with *Bostrychoceras polyplocum* which he attached to the Maestrichtian. Therefore, he considered the Maestrichtian (in his sense) as comprising two ammonite zones, an upper with *Pachydiscus neubergicus* (=Maestrichtian) and a lower with *Bostrychoceras polyplocum* (=uppermost Campanian), although the latter species has never been recorded in the type Maestrichtian or in its junior synonym, the Dordonian.

This downward extension of the Maestrichtian as suggested by Haug was followed by Spath (1926), Laffitte (1934, 1939), Marie (1937, 1943), Gignoux (1943, 1950), Muller & Schenck (1943) and Mikhailov (1947, 1948) as well as many other authors, and has confused the position of the Campanian–Maestrichtian boundary.

On the other hand, Cornet & Briart (1874), followed by Umbgrove (1925, 1926), Withers (1935), Bubnoff (1935), Van der Heide (1954), etc. restricted the Maestrichtian stage to the Maestricht tuff and its equivalents only, but this did not solve the problem of the Campanian–Maestrichtian boundary. To overcome this difficulty, Leriche (1927, 1929), quite justifiably, included in the Maestrichtian, all Upper Cretaceous strata in the type area of Dumont, which are older than the Danian of Desor (1846) and younger than the Senonian of d'Orbigny (1842) and the Campanian of Coquand (1857). This concept, which clearly signifies that no equivalents of the Maestrichtian occur in the type Senonian of d'Orbigny, created a tendency among various authors to regard the Maestrichtian separately from the Senonian. This has been substantiated by the fact that Schijfsma (1946) considered the Foraminifera of the *Belemnitella mucronata* chalk of the Paris Basin, which represents the upper part of d'Orbigny's Senonian, to be of Middle and Upper Campanian age, and thus he denied the presence of Maestrichtian in the Paris Basin, although Marie (1943) considered the Meudon Chalk to be of Maestrichtian age.

Visser (1951) studied the Foraminifera of the type " Maestricht tuffaceous chalk ", reviewing previous studies and discussing the various usages of the term Maestrichtian. She mentioned that while Gignoux (1936–1950), followed by most French stratigraphers, had equated the Maestrichtian with the *Belemnitella mucronata* Zone, Muller & Schenck (1943) equated it with the *B. lanceolata* Zone, restricting the *mucronata* Zone to the Campanian, and Brotzen (1936) considered the *mucronata* Zone to be younger than the Maestrichtian. On the other hand Schijfsma (1946) considered the *B. mucronata* Zone to represent both the Upper Campanian and the Maestrichtian, while he considered the Middle Campanian to be represented by a particular horizon in which both *B. mucronata* and *Goniatheutis quadrata* occur, and the Lower Campanian to be represented by the *G. quadrata* Zone only. She also mentioned that while in Belgium and Holland the term Maestrichtian *s.s.* is generally used to describe both the Maestricht tuffaceous chalk and the Kunrade chalk, the term Maestrichtian *s.l.* (or the Maestrichtian as understood by French authors) includes the underlying Gulpen chalk as well. Following Schijfsma (1946), she considered the oldest Cretaceous outcrops in Limburg (the Heervian and the Aachen sands) as belonging to the Middle Campanian. However, as her study was mainly concerned with the Maestricht tuffaceous chalk, she could not precisely define the lower boundary of the Maestrichtian.

Jeletsky (1951), following Leriche (1927, 1929) and Schijfsma (1946) considered the Maestrichtian as " . . . . . an independent stage younger than and equal in rank to the Senonian stage . . . . ", while he considered the Campanian as the upper substage of the Senonian. He stated that " The latest research of Abrard (1931 pp. 24–5 ; 1948 pp. 231, 233, 279–280) has, indeed, shown that at the type locality of the Campanian stage in southwest France, near Champagne, the beds with *Bostrychoceras polyplocum* (Roemer) . . . . . , were originally included in upper Campanian and not in lowermost Dordonian (an invalid synonym of Maestrichtian) ".

Jeletzky's proposition was questioned by Van der Heide (1954) because it meant a slight change of the Maestrichtian as originally defined by Dumont (1849). However, as previously mentioned by Romein (1961, 7^{e} Colloque European de Micropaléontologie, Pays-Bas et Belgique, Guide d'Excursions, B. Upper Cretaceous, Limbourg : 1–3) the confusion and ambiguity of Dumont's definition of the term Maestrichtian, led to the fact that the term has evolved through the times, independently from the original definition of the type locality. The succession in the type area which is known under the names of the tuffaceous limestone of Maestricht (Ma–Md) and the Gulpen chalk (Cr_4) is generally considered to be of Upper Maestrichtian age (Meyer 1959 and Voigt 1960). However, Romein (1962) extended the Maestrichtian in its type area downwards to include most of the Gulpen chalk [Cr_{3b} (in part)—Cr_4], and the Maestricht chalk (Ma–Me) which he partly equated with the Kunrade chalk.

In 1959, the "Congrès des Sociétés Savantes de Paris et des Départements" held at Dijon, discussed the stratigraphical and palaeontological problems of the Upper Cretaceous in France " Colloque sur le Crétacé Supérieur Francais ". In spite of numerous disagreements, the congress came to the following conclusions :

1. The *Bostrychoceras polyplocum* Zone which has always been assigned to the Lower Maestrichtian, is considered to be of Upper Campanian age.
2. The Maestrichtian is limited to the zone of *Pachydiscus neubergicus*.
3. Although strictly speaking the Maestrichtian should be excluded from the Senonian, it is generally admitted in France that the Upper Senonian includes both the Campanain and the Maestrichtian ; being more practicable the committee proposed to continue this usage.

However, until the type sections of the Senonian and Maestrichtian are studied in detail and correlated more precisely, it is advisable to treat the Maestrichtian separately from the Senonian. Thus in the present study, the Maestrichtian is considered as an independent stage, younger than, and equal in rank to, the Senonian stage as suggested by Jeletzky (1951), although it is clearly understood that the time span represented by the Maestrictian is much shorter than that of the Senonian. Again, the zone of *Bostrycoceras polyplocum* and its associated fauna which has been wrongly considered to mark the base of the Maestrichtian, is here assigned to the Upper Campanian, as the species, although rare in the Aquitaine Basin in general, has been recorded in the type Campanian only (Jeletzky 1951 and Mrs. M. Séronie-Vivien, personal communication). Moreover, in spite of the accumulated indisputable evidence for the Upper Cretaceous age of the type Maestrichtian, Hofker, in several publications (1955–62), has argued for the time-stratigraphic equivalency of the type Maestrichtian and the type Danian. Hofker's claims were discussed by Loeblich & Tappan (1957*b*) and Berggren (1962) who showed clearly that the true stratigraphical relationship between the Danian and the Maestrichtian stages is one of superposition and not lateral equivalence.

STRATIGRAPHICAL POSITION OF THE DANIAN

Desor (1846) introduced the Danian as the youngest stage of the Cretaceous system, typified by the succession of the *Cerithium*, bryozoan, coralline and coccolithic limestones, which disconformably overlies the Senonian white chalk of Denmark. He considered these Danian deposits as equivalent to the so-called " pisolitic limestone " which similarly overlies the Senonian white chalk disconformably at Laversines and Vigny in the Paris Basin, and which were generally considered, at that time, to be of Upper Cretaceous age. In his definition of this new stage he stated : " M. Desor pense dès lors qu'il faut envisager le calcaire de Faxoë, la craie corallienne et le lambeau pisolithique de Laversine et de Vigny, comme un étage particulier de la craie, le plus récent de tous, ainsi que l'avait proposé M. Elie de Beaumont ; mais il ne saurait y comprendre les terrains à *Nummulites*, qu'il envisage comme étant d'une époque plus récente. M. Desor propose d'appeler cet étage terrain danien, parce qu'il est surtout développé dans les îles du Danemark. Ainsi que l'avait proposé M. Graves, il est probable qu'on devra y rapporter par la suite le terrain de Maestricht ".

Six years later, d'Orbigny (1852) described the fauna of the type Danian, and in agreement with Desor, he considered it as the youngest stage of the Cretaceous system, but clearly distinguished it from the underlying Maestrichtian. Since then the same concept has been automatically followed by most stratigraphers, in spite of the doubts about the true Cretaceous nature of the type Danian fauna. Indeed, the Tertiary affinities of this fauna have been pointed out as early as 1823 by Forchhammer, (see Rosenkrantz 1960), long before the establishment of the term, and later by Starkie Gardner (1884) and a few other authors.

On the other hand, Desor, in his original definition of the term, mentioned that the beds of Maestricht may possibly be included within his Danian stage. This vague statement led various authors to extend the Danian downwards in the succession to include the Maestrichtian and even the Campanian, in spite of the marked stratigraphical break between the Danian and the underlying strata in both the type region of Desor and in other parts of the world. Thus, Mayer-Eymar (1872) considered the Danian to include the Campanian of Coquand, the Maestrichtian of Dumont and the Danian of Desor, while Hébert (1875) extended the Danian downwards to include the Maestrichtian rocks only. On the other hand Munier-Chalmas & de Lapparant (1893) distinguished the Danian from the Maestrichtian, but extended the former upwards in the section to include the Montian as its upper substage and the typical Danian as its lower, including them both in the Cretaceous system. Again, Geikie (1903) considered the Danian to include the Maestrichtian as its lower part and the Montian as its upper, while Denizot (1936) considered the Maestrichtian to be distinct from the Danian, although he included it as a substage of the latter.

This arbitrary use of the term Danian, resulted in the fact that the literature is now filled with a considerable amount of wrong and confused information which led to the vagueness and ambiguity of the term, and made it difficult to decide its true stratigraphical position.

However, de Grossouvre (1897, 1901) considered both the Danian and the Montian as a single unit in the basal Tertiary. He reasoned that as the Danian is devoid of the index fossils which characterise the Cretaceous rocks below, such as the ammonites, belemnites, inocerami, trigonias, rudists (*Hippurites*, *Spherolites* and *Radiolites*), etc., the Cretaceous–Tertiary boundary should be drawn at the base of the Danian. Unfortunately, this valuable remark was received with little enthusiasm, and most stratigraphers continued to use the term Danian in the sense of Desor (1846) and d'Orbigny (1852), as the youngest stage of the Cretaceous system.

Nevertheless, this logical explanation of the Cretaceous–Tertiary boundary suggested by de Grossouvre, has started, since the early days of this century, to gain the support of a few geologists, e.g. Brünnich-Nielsen (1920), Rosenkrantz (1920), Harder (1922), Kayser (1924), Keller (1946), and Morozova (1939), who clearly demonstrated the Tertiary affinities of the Danian fauna and thus advocated its position at the base of the Tertiary.

Although faced with strong opposition and neglect at that time, this proposition has recently received overwhelming support by a great number of stratigraphers, e.g. Jeletzky (1951–1962) Brönnimann (1953), Troelson (1957), Loeblich & Tappan (1957*a*, *b*), Bolli (1957*b*), Nakkady (1957), Bolli & Cita (1960*a*, *b*), Hay (1960), Lys (1960), Reyment (1960*a*, *b*) Burollet & Magnier (1960), Rosenkranz (1960) and Berggren (1960*b*, 1962). These recent studies have shown that the Danian, in its type region and in various parts of the world is separated from the Maestrichtian rocks below by a distinct faunal break which is generally accompanied by a physical break of varying magnitude. The pronounced nature of this break and its world-wide extent clearly mark the Maestrichtian–Danian boundary as the natural boundary between the Mesozoic and the Cainozoic eras, and justifies the position of the Danian at the base of the Tertiary system. At the Maestrichtian–Danian boundary, all the *Globotruncana*, *Rugoglobigerina*, *Trinitella*, *Plummerita*, *Abathomphalus*, *Hedbergella*, *Globigerinelloides*, *Schackoina*, *Pseudotextularia*, *Pseudoguembelina*, *Gublerina*, *Planoglobulina*, *Racemiguembelina*, and *Heterohelix*, among a large number of microfossils ; all the ammonites, the true belemnites (Belemnitellidae), rudists, inocerami (?) ; all the mosasaurs, plesiosaurs, ichthyosaurs ; all the dinosaurs and pterodactyls, etc. were found to die out completely and to be replaced in the overlying Danian by a different fauna where *Globigerina*, *Globigerinoides*, *Globorotalia*, *Chiloguembelina*, typical Tertiary molluscan and echinoderm fauna, and primitive placental mammals made their appearance for the first time. This geologically abrupt extinction of several typical representatives of Mesozoic life at the Maestrichtian–Danian boundary, which is followed by an equally abrupt appearance of definite Cainozoic forms in the Danian rocks above, and which is documented in both the marine and non-marine domains, clearly marks this boundary as the major biochronological line between the Mesozoic and the Cainozoic Eras. This is substantiated by the fact that this major break is also accompanied by a pronounced change in the generic and specific composition of many other groups such as the molluscs (Rosenkrantz 1960), the echinoderms (Poslavskaya & Moskvin 1960), the coccolithophorids (Bramlette & Sullivan 1961), as well as by a physical break of varying magnitude and world-wide extent. On the other hand, many other species and genera survived this change and continued their development from the Maestrichtian into the Danian or even later stages. These were used by various authors as an argument for the Cretaceous and/or the transitional character of the Danian fauna, and hence their preference to include the Danian within the Cretaceous system. However, this does not minimize the importance of the distinct stratigraphical break between the Maestrichtian and the Danian, as survival of certain members of the organic life across similar major faunal breaks is reasonably understood and clearly documented in the history of the earth. Moreover, contrary to Brotzen (1959), the faunal break between the Maestrichtian and the overlying Danian is definitely much more pronounced and widespread than any known breaks between the Danian and the overlying stages, or between the Maestrichtian and the underlying stages. Therefore, the Mesozoic–Cainozoic contact is naturally placed at this boundary which is, as described by Jeletzky (1962), " a natural boundary based on a unique and easily recognizable, major biochronological event apparently reflecting some kind of a radical, world-wide change in the physical regime of our planet ".

Thus in the present study, the Danian is considered as the oldest stage of the Tertiary system, and the Maestrichtian–Danian contact is taken to mark the Mesozoic–Cainozoic boundary. This is in spite of the fact that various authors (e.g. Brotzen 1959 and Yanshin 1960) have strongly argued for, and continued to use the term Danian in the sense of Desor, as the youngest stage of the Cretaceous system. However, neither of these authors could provide any evidence against the definite Tertiary character of the Danian fauna or the marked faunal break between the Maestrichtian and the overlying Danian. Brotzen simply stated " To range the Danian with the Cretaceous or the Tertiary is only a question of convention ", and unjustifiably added " In my opinion no fundamental evidence has been adduced which will necessitate changing the classical range of the Danian as the youngest stage of the Cretaceous to the oldest stage of the Tertiary ". Yanshin built his argument on a completely unsound basis and his paper is full of confusion and numerous mistakes in matters of fundamental importance.

Nature of the Mesozoic–Cainozoic Boundary

The traditional usage of the Danian as the youngest stage of the Cretaceous system instead of its true position at the base of the Tertiary, has always concealed the nature of the Mesozoic–Cainozoic boundary which in most parts of the world is marked by a distinct stratigraphcial break.

In addition to the indisputable, major faunal break between the Maestrichtian and the overlying Danian, the latter was found, in various parts of the world, to be separated from the Cretaceous rocks below by physical breaks of varying magnitude. In places, where the Upper Cretaceous–Lower Tertiary succession was described to be conformable throughout, (e.g. Egypt), unconformities and disconformities are being discovered with further detailed examination of the previously described sections (e.g. Farafra, Dakhla and Kharga Oases and the Esna–Idfu region). In places where the lithology on either side of the contact does not permit the detection of the physical break, the abrupt extinction of numerous, diverse representatives of Cretaceous life, and the sudden appearance of new Tertiary forms, clearly mark the Mesozoic–Cainozoic contact.

Although evident and clearly documented, such a distinct, sharp and world-wide break at the Maestrichtian–Danian boundary, represents one of the most enigmatic problems in the history of the Earth. It is beyond the scope of the present work to try to explain it, but it clearly points to the fact that the life record between the uppermost Maestrichtian and the lowermost Danian, as we know it, is incomplete and may possibly be sought for in the deep oceanic troughs, or in yet undescribed sections, where a complete Cretaceous–Tertiary sequence may be found. Moreover it reflects, as previously mentioned by Jeletzky (1962) " some kind of a radical, world-wide change in the physical regime of our planet ", which may be regarded as a " catastrophe " or a " revolution ", and which still awaits further explanation.

Stratigraphical Position and Classification of the Paleocene

Schimper (1874) introduced the term Paleocene to distinguish the lowest part of the Tertiary system, which was then included at the base of the Eocene. He used this term to describe the " Travertin de Sézanne " in the eastern part of the Paris Basin, which he considered on the basis of its floral content to be worthy of distinction from both the younger Eocene and the older Upper Cretaceous series. The conglomerates of " Meudon " and " Cernay " which are characterized by their mammalian fauna were also attached to the Paleocene and were found to mark the limits of a sedimentary cycle which followed the Cretaceous chalk and preceded the " Nummulitic transgression ".

Thus the Paleocene was generally considered to represent one sedimentary cycle spanning the time between the uppermost Cretaceous and the basal Eocene, although the controversy about the true position of these two boundaries made it difficult to establish the boundaries of the Paleocene series. For example, the so called " pisolitic limestone " of Laversines and Vigny and its equivalents, in the Paris Basin which represent the first marine transgression over the truncated surface of the Upper Cretaceous Chalk, were repeatedly assigned to the Campanian, Maestrichtian or Danian. As a result, these beds were generally excluded from the Paleocene, although they have been recently proved to be of definite basal Tertiary age and correlated with the " Tuffeau de Ciply " of Belgium (Damotte & Feugueur 1963). Similarly the lagoonal, clayey and lignitic deposits which lie between the " Cernay conglomerate " or its equivalents and the base of the Cuisian, were included by some authors within the Paleocene, while others placed them at the base of the Eocene. Therefore, the Paleocene in the Paris Basin was very poorly defined and was generally taken to include various rock units between the Upper Cretaceous and the basal Eocene such as the " Tuffeau de la Fère " and the " Argile de Vaux-sous-Laon " ; the " Sables de Bracheux et de Chalons-sur-Vesle " ; the " Travertin de Sézanne " ; the " Calcaire de Rilly " and the " Conglomerat de Cernay ", and by some authors the " Argile plastique " and the " Lignites du Soissonnais " as well, but its lowermost and uppermost limits remained uncertain. Moreover, the fact that the Paleocene, as defined above, in its type region, is represented by non-marine and very near-shore deposits which were mainly zoned on the basis of their floral and mammalian contents, made any correlation with the corresponding marine deposits practically impossible. The shallow water marine fauna of the " Sables de Bracheux " and its equivalents, which were described by Farchad (1936) and Rouvillois (1960) proved to be largely of a localized nature and hence, of little value in correlation.

As a result, various authors, e.g. Mangin (1957), suggested that the term Paleocene should be dropped altogether and the Eocene be extended downwards (as it was originally defined) to include at its base the youngest Lower Tertiary formations. However, the fact that the Paleocene, in its type region and in other parts of the world is generally represented by a particular sedimentary cycle and/or biological unit, distinguished from that of the overlying Eocene, favours its separate treatment.

On the other hand, long before the introduction of the term Paleocene, several stages had been established to describe various segments of the succession representing the time span between the uppermost Cretaceous and the basal Eocene, e.g. the Landenian (1839), the Heersian (1851), the Montian (1868) and the Thanetian (1873). In addition various stages were introduced later, e.g. the Sparnacian (1877), the Seelandian (1924) and the Ilerdian (1960). Moreover, the Danian which was wrongly introduced (1846) as the youngest stage of the Cretaceous system, was proved, as stated above, to represent the oldest stage of the Tertiary, and is thus included as the lowest stage of the Paleocene series. However, as these type sections are widely spaced, were designated by different authors, and are represented by different facies (continental, lagoonal, shallow-water and deep-water marine deposits), it became difficult to establish the true stratigraphical relationship between one stage and the other, and between each stage and the corresponding part in the type area of the Paleocene. Nevertheless, to avoid the difficulty of correlation with the peculiar facies of the type Paleocene in the Paris Basin, different authors tended to use various sets of the above-mentioned stage names to represent the basal Tertiary, as subdivisions of the Paleocene, or within the basal part of the Lower Eocene. Moreover, they tried to introduce these stage names to the type Paleocene, but the relationship between one stage and the other was not clearly understood, and was arbitrarily interpreted by the individuals concerned. Thus, while the Paleocene in the Paris Basin was regarded as including the Thanetian and Sparnacian ; the Montian, Thanetian and Sparnacian ; the Montian and Thanetian ; or the Thanetian alone, it was taken to include the Montain and Landenian in southern Belgium ; the Montian, Heersian (with or without the Infra-Heersian) and Landenian in north-eastern Belgium and in Holland ; the Thanetian, with or without the Woolwich and Reading Beds in England ; the Seelandian, Thanetian and Landenian in Sweden and Denmark, and any further combination of these, plus or minus the Danian. Moreover, because of the confusion about the true chronological relationship between the Danian and the Montian, Sigal (1949), followed by most Mediterranean geologists, introduced the Dano-Montian as a new term to cover the early Paleocene period.

However, in his study of the basal Tertiary in the Franco-Belgian Basin, Feugueur (1955, 1962, 1963) included the Paleocene within the Lower Eocene and equated the Cuisian with the Upper Ypresian, the Sparnacian with the Lower Ypresian, and the Thanetian of the Paris Basin with the Landenian of Belgium, although he pointed out the fact that the Lower Landenian (=Heersian) is missing in the Paris Basin. Feugueur followed Leriche (1903) who had previously recognized in the Landenian a marine lower division and a continental upper one, and divided the marine Lower Landenian, on the basis of its shallow water molluscs, into three zones, from the base upwards: the *Arctica morrisi* Zone, the *Pholadomya oblitterata* Zone and the *Arctica scutellaria* Zone. However, Feugueur considered the latter zone to be of lagoonal, rather than of marine origin and attached it to the overlying Upper Landenian, which he regarded as comprising the lagoonal *Arctica scutellaria* Zone at its base and the continental *Physa gigantea* Zone on top. On the other hand, while Feugueur equated the so-called " Thanetian of the Paris Basin " with the Landenian of Belgium, and noted that the basal Landenian (=Heersian=*Arctica morrisi* Zone) is missing in the Paris Basin, *Arctica morrisi* was found to mark the top of the Thanetian in England. In spite of this fact, the so-called Thanetian in the Paris Basin has always been equated with the Thanetian of England, which is apparently much older. Thus, despite the value of Feugueur's correlation in the Anglo-Franco-Belgian basin, several problems in the same basin were left unexplained. The relationship between the Thanetian of England and the Thanetian of the Paris Basin ; the Thanetian of England and the Landenian of Belgium ; the Thanetian, the Landenian and the Montian ; the Montian and the Danian ; the Danian and the Heersian ; and the Heersian and the Montian are still not clear. Moreover, the relationships of the other type stages of the Paleocene outside the " Anglo-Franco-Belgian Basin " to each other and to those in the basin were left unsolved. It is not really understood what sort of chronological relationship exists between the Danian and Montian, the Montian and Seelandian, the Montian and Landenian, the Thanetian and Landenian, the Montian, Thanetian, Landenian and the Ilerdian, in their respective type areas. Nevertheless, selected sets of these stage names were arbitrarily used by various authors to represent the Paleocene, but were differently interpreted and much confused.

Loeblich & Tappan (1957*a*, *b*) divided the Paleocene into a lower and an upper stage which they equated with the Danian and Landenian respectively. They (1957*a*) suggested the inclusion of the Thanetian as the lower substage of the Landenian and the Sparnacian as the upper one, although they mentioned (1957*b*) that the Sparnacian may represent both late Paloecene and early Eocene time. These authors recorded the occurrence of *G. daubjergensis* Brönnimann and *G. triloculinoides* Plummer in the lower part of the type Montian (the " Tuffeau de Ciply "), and thus considered the type Montian as the lateral equivalent of the type Danian, and stated " The occurrence of the Cerithium fauna in the type Danian, and the *Nautilus danicus* in Montian equivalents, the species of the *daubjergensis-compressa* faunal zone represented in both type Danian and type Montian and their equivalents over the world, the identical stratigraphic position of the Danian and Montian, each unconformable on the Cretaceous, and underlying the Landenian sediments, and the fact that they are never found together, leads inescapably to the conclusion that the Danian and Montian are merely different lithologic and faunal facies of identical geologic age. We suggest that the term Danian be used to include the Montian also, inasmuch as the type Danian includes beds of both facies. The Danian should be used as a stage name within the Paleocene ".

Loeblich & Tappan's proposition was previously mentioned by de Grossouvre (1897) and Harder (1922), and is followed by a number of authors, in spite of the fact that Vincent (1928), Ravn (1933), Chavan (1946), Marie (1950), Hofker (1961*a*, 1962*a*), Moskvin & Naidin (1960) and Voigt (1960) have strongly emphasized the fact that the type Montian is younger than the type Danian.

Hofker (1961*a*) recorded the occurrence of *Globorotalia pseudomenardii* Bolli, *Globorotalia ehrenbergi* Bolli and *Globorotalia pusilla laevigata* Bolli in the lower part of the type Montian (the " Tuffeau de Ciply "), and thus correlated the Montian with the *Globorotalia pusilla pusilla* and the *Globorotalia pseudomenardii* Zones of Bolli (1957*b*). On these grounds, he considered the Montian to be of Middle Paleocene age and introduced what he described as the Lower Paleocene between the Danian and the Montian, correlating it with the Seelandian of Brotzen (1948), and stating that " Alors, il n'y a plus de doute : le Montien-type, vers sa base, est déjà du Paléocène moyen et il est impossible de paralléliser le Montien avec le Danien ; il y a un étage entier entre le Danien et le Montien, représenté par le Tuffeau glauconieux, qui, déjà est du Paléocène, comparable aux couches plus basses du ' Lizard Springs formation du Trinidad ' ". Moreover, he added that the benthonic Foraminifera of the " Calcaire grossier de Mons ", which forms the upper part of the type Montian, leaves no doubt about its Upper Paleocene age, although the planktonic Foraminifera are very rare and do not form a typical association. He further complicated the problem by considering the Montian as the upper part of the Lower Paleocene and the *G. trinidadensis*–*G. uncinata* Zones of Bolli as representing the lower part of this Lower Paleocene, which overlies the Danian. Again, he stated that the Landenian overlies the Montian, and that it contains in its lower part a benthonic foraminiferal fauna comparable to that of the Thanetian of England, but with no pelagic forms. He did not state to which part of the Paleocene the Thanetian belongs if the " Calcaire de Mons " is considered to be of Upper Paleocene age as he suggests.

Thus, in a single paper, Hofker considered the Montian to be equivalent to the upper part of the Lower Paleocene, to be Middle Paleocene in age and (as the " Calcaire de Mons ") to be of Upper Paleocene age. However, the existence of *G. daubjergensis* Brönnimann in the " Tuffeau de Ciply ", discovered by Loeblich & Tappan (1957*b*), confirmed by the present author, by Gartner & Hay (1962) and by Berggren (1963), throws doubt on the validity of Hofker's record, especially of *G. pseudomenardii* and *G. pusilla pusilla.* In the Esna–Idfu region and in other parts of the world, the last mentiond species occur at a much higher level in the Paleocene succession than the uppermost limit of *G. daubjergensis.* Moreover, the writer has examined washed residues of the " Tuffeau de Ciply" in Dr. Hofker's possession and others placed by him in the collection of the Geological Museum at Haarlem but could not trace these species, in spite of Hofker's statement that he had found them in abundance. On the contrary, in the latter collection, forms such as *G. trinidadensis* Bolli and *G. uncinata uncinata* Bolli (together with undescribed forms) deny the possibility of the existence of *G. pseudomenardii* in the " Tuffeau de Ciply ". The present author has sampled the type "Tuffeau de Ciply ", and the outcrop of the " Calcaire de Mons " at the " Trenchée de Hainin " in the Mon's basin. These samples together with one from the type " Calcaire de Mons " of the " Puits Goffint " and several Montian samples from drilling in the Mons and the Landen Basins, kindly provided by Mr. M. Gulinck and Professor R. Marlière, are still under study. Until this study is completed no decision can be reached regarding the true stratigraphical relationship between the Danian and the Montian. However, authors have already divided into three groups ; one advocating the time-stratigraphic equivalency of the type Danian and the type Montian ; another claiming a much younger age for the Montian and placing it higher in the Paleocene; and a third who clearly realizes the close similarity between the Danian and Montian faunas, but who still advocates placing the Montian on top of the Danian.

In support of the latter proposition, Voigt (1960) stated that " Researches now in progress of the bryozoa of the Montian in Belgium and Holland show very close relationship to the bryozoan fauna of the Danian, however ; a considerable part of foreign, in part new, species still leaves a possibility for the lower Montian, the " Tuffeau de Ciply ", to be younger than upper Danian."

In agreement with Voigt (1960) Moskvin & Naidin (1960) recorded the occurrence, in southwestern Russia (Crimea, Caucasus and Transcaspian Oblast), of a limestone horizon with a molluscan fauna similar to that described from the type Montian, directly overlying bryozoan and crinoidal limestone with typical Danian fauna. Thus these authors concluded that the time-stratigraphic equivalency of the type Danian and the type Montian as suggested by Loeblich & Tappan (1957*a*, *b*) is practically impossible. However, because of the close relationship of the fauna, they considered the Montian as the upper substage of the Danian as previously suggested by Munier-Chalmas & de Lapparent (1893), and divided the Paleocene into a lower, Danian and an upper, Thanetian stage.

On the other hand, Gartner & Hay (1962) recorded the occurrence of a specimen closely resembling *Globigerina daubjergensis* Brönnimann in the " Tuffeau de Ciply ". This record is confirmed by the present author, and by Berggren (1963) who recorded this species together with *Globigerina triloculinoides* Plummer and *Globorotalia pseudobulloides* (Plummer) at the base of the same formation. Berggren quoted Wienberg-Rassmussen (1962) who considered the " Tuffeau de Ciply ", on the basis of its Echinoderm fossil content, to be of definite Danian, and presumably Middle Danian age, and concluded that " . . . the lower Montian (Tuffeau de Ciply) is time-equivalent with the lower and middle Danian of Denmark ; the relationship between the upper Montian (Calcaire de Mons) and the upper Danian remains uncertain. By extrapolation it is probably correlative in part with the upper Danian, and, in part, younger than known, exposed Danian in Denmark. It is also possible that subsurface younger Danian in Denmark may fill the missing void in our information . . .".

Loeblich & Tappan (1957*b*), also studied samples from both the type Thanetian and the type Sparnacian and stated that no planktonic Foraminifera were found in the samples from these sections. They quoted Haynes (1955) who had previously recorded *Globigerina triloculinoides* Plummer, *G. pseudobulloides* Plummer and *G. velascoensis* (Cushman) aff. var. *acuta* Toulmin from type Thanetian samples. Thus they equated the Thanetian with " the highest Paleocene planktonic faunal zone—the *Globorotalia velascoensis–acuta* Zone ". However, on their correlation diagram (1957*a*, fig. 28) they equated the Sparnacian with this zone, which they considered as the upper subzone of their " Landenian " *angulata* Zone, while they regarded the Thanetian as the lower part of this zone, the *pseudobulloides* Subzone.

However, examination of *Globorotalia velascoensis* (Cushman) aff. var. *acuta* (Toulmin) of Haynes (1955, 1956) from the type Thanetian of England, has shown that it is a reworked Upper Cretaceous *Globotruncana* species. The state of preservation of the specimen does not allow its specific identification with certainty, but the occurrence of reworked Upper Cretaceous species in the type Thanetian was mentioned by Haynes (1956), and these species have been studied by Haynes and El-Naggar (in press). The same conclusion has been reached independently by Berggren & Barr (*in* Berggren 1963).

Nevertheless, this record by Haynes (1955, 1956) was used by Loeblich & Tappan (1957*a*, *b*), Bolli & Cita (1960 *a*, *b*), and several other authors as a basis for correlating the type Thanetian with the *Globorotalia velascoensis* Zone of Upper Paleocene age. However, examination of several type Thanetian samples has shown that they contain a mixture of Senonian and Danian forms. The existence of such forms as *Globigerina daubjergensis*, *G. triloculinoides*, *Globorotalia pseudobulloides*, *G. trinidadensis*, *G. quadrata*, which are clearly Danian in age, with forms such as *Globotruncana cretacea*, *G. linneiana linneiana*, *G. fornicata fornicata*, *G. rosetta rosetta*, *G. tricarinata*

tricarinata, and abundant *Rugoglobigerina*, *Hedbergella* and *Globigerinelloides* species, which indicate an Upper Senonian, pre-Maestrichtian age, and the entire absence of typical Maestrichtian forms, represent one of several enigmatic problems about the true stratigraphical position of the Thanetian, and the geological history of England during the Cretaceous–Tertiary transition period. The existence of mixed Senonian and Danian fauna in the type Thanetian may be explained by the suggestion that the whole planktonic foraminiferal content is reworked from previously existing Senonian and Danian strata, although no Danian deposits have yet been recorded anywhere in the British Isles. This may be substantiated by the record, in the type Thanetian, of a meagre calcareous nannoplankton assemblage which also occurs in the " *G. pseudomenardii* Zone of Trinidad " (Bramlette & Sullivan 1961). On the other hand, it could suggest that while the Senonian forms are reworked from the underlying chalk, the Danian ones are possibly indigenous ; hence the type Thanetian may include strata which are equivalent to the type Danian. This conclusion is doubted here owing to the absence of a typical Danian macrofauna and fauna of benthonic Foraminifera. However, the author refrains at present from taking any decision about the true stratigraphical position of the Thanetian until its type sections are examined in detail and correlated with the other type sections of the various stages of the Paleocene, and with the Paleocene in other parts of the world. Nevertheless, the Thanetian of England is probably different from the Thanetian in the Paris Basin ; while *Arctica morrisi* marks the top of the former, it is supposed to underlie the latter. This simply points to the fact that the true stratigraphical position of the Thanetian, like that of the Montian, is not yet clearly understood and that the vague use of these terms in Paleocene stratigraphy is far too dangerous at the moment.

Loeblich & Tappan (1957*b*) also mentioned the difficulty in correlating the Sparnacian, as it is represented in its type section by non-marine facies. However, they mentioned that as the non-marine Woolwich and Reading Beds and the underlying marine Thanet Beds of England, are considered as deposits of one and the same sedimentary cycle (Stamp 1921 ; Haynes 1955), the non-marine type Sparnacian is more probably related to the Paleocene. Moreover, they stated that " Until marine strata referable to the Sparnacian can be obtained this problem is difficult to solve. It may represent both late Palocene and early Eocene time ". However, on their correlation diagram they considered the Sparnacian as the upper substage of the Landenian, although Feugueur (1955, 1962, 1963) has constantly advocated the time-stratigraphic equivalency of the type Sparnacian and the lower Ypresian.

This brief discussion clearly indicates the great difficulty in correlating the various stages and substages of the Paleocene, because of the non-marine, or very near-shore facies of most of the type sections, and the uncertainty about their true chronological relationship. It also indicates that the assignment of the various planktonic foraminiferal zones by Loeblich & Tappan (1957*a*, *b*), Bolli (1959), Bolli & Cita (1960*a*, *b*), Hofker (1961*a*, 1962*a*) and various other authors, to the Montian, Thanetian, Sparnacian, or Landenian, is rather arbitrary and is not based on any proper correlation with the type sections.

To overcome the difficulty of correlating marine and non-marine deposits and the uncertainty resulting from such correlation, Hottinger & Schaub (1960) proposed the Ilerdian as a new stage to represent the marine Upper Paleocene. These authors studied the larger Foraminifera of this new stage and stated that it has no equivalent in the Paris Basin, but added " We only know that it is immediately below the Cuisian. Very likely it lies between the Cuisian and the marine phase of the Montian. So far we had no opportunity to determine whether a part—and in the affirmative case, which part—of this stage corresponds with the marine phase of the Landenian."

Gartner & Hay (1962) studied the planktonic Foraminifera of the type Ilerdian, and affirmed its Upper Paleocene age. However, examination of several Ilerdian samples from Mont Cayla, kindly presented by Miss M. Toumarkine of the Sorbonne, has shown that these deposits are of Lower Eocene, rather than of Paleocene age (see discussion under each of the species recorded by Gartner & Hay 1962). This throws doubt on Hottinger & Schaub's conclusion, on Gartner & Hay's identifications and on the validity of the Ilerdian as a stage of the Paleocene. The use of the term Ilerdian in Paleocene stratigraphy is therefore considered inadvisable, especially as the relationship of the " Ilerdian " to the other stages and substages of the Paleocene is not yet understood. [The type section of the Ilerdian in the Tremp basin, as well as several other Ilerdian outcrops in Spain and in France, have been sampled in detail by the present author in an attempt to discover their true stratigraphical positions.]

In the present study, the Paleocene is considered to be a distinct series at the base of the Tertiary system, older than, and equal in rank to, the Eocene series. It spans the time between the top of the Cretaceous and the base of the Eocene, and includes the Danian as its lowest stage. The controversy about the chronological and stratigraphical relationships of the various stages and substages of the Paleocene (other than the Danian) as summarized above, necessitates the temporary abandonment of these terms and the use of faunal zones instead. The establishment of faunal zones which are built on the basis of evident evolutionary trends, and which can be correlated in various parts of the world, is the only solution at the moment to the numerous problems in Paleocene stratigraphy. Correlation of the type sections of the various stages and substages of the Paleocene with these zones is bound to show the true stratigraphical relationship between one stage and the other, and will lead to the development of a reliable means of correlation for this series.[2]

The present study has shown that in Egypt and elsewhere, the Paleocene is divisible into three faunal zones in which the planktonic Foraminifera represent a continuous evolutionary sequence showing clearly recognizable trends. Each of these zones corresponds to a definite evolutionary stage. They are as follows :

1. A lower zone marked by the first appearance at its base of the genera *Globorotalia* and *Globigerina*, and characterized by an assemblage of *Globigerina* and globi-

[2] The relationship between these stages has now been clarified and the suggested stage names are discussed elsewhere (El-Naggar, in press), and inserted on some of the accompanying figures.

gerina-like, rounded, non-keeled *Globorotalia*. These globorotalias are generally smooth-surfaced, with a tendency towards the development of a slightly roughened surface and a gently compressed test upward in the section. This zone is characterized by the presence of *Globorotalia pseudobulloides* (Plummer), *G. trinidadensis* Bolli, *G. compressa* (Plummer), *Globigerina triloculinoides* Plummer and *G. daubjergensis* Brönnimann among other species, but as both *Globorotalia compressa* and *Globigerina daubjergensis* are found to die out completely at its top, they are taken as the index species of the zone, which is known as the *Globorotalia compressa/Globigerina daubjergensis* Zone. The planktonic Foraminifera of this zone characterizes the Danian in its type section and the known Danian deposits elsewhere, thus it is taken to represent the Danian, or the oldest stage of the Paleocene series. The lower limit of this zone marks the Cretaceous–Tertiary contact, and its upper limit is marked by the disappearance of its index species and the first appearance of the truncated *Globorotalia* which characterize the following zone.

2. A middle zone characterized by an assemblage of *Globigerina* and truncated, non-keeled *Globorotalia*, in addition to the rounded form which first appeared in the underlying zone. At the base of this zone, most representatives of the genus *Globorotalia* (generally rounded or slightly compressed in the underlying zone) start to become flattened on the dorsal side and strongly protruding on the ventral, with the development of an acute axial periphery, but with no keel, or only a partially developed, incipient one. Again the tendency towards the development of a roughened surface, flattening of the dorsal side and the development of a sharply acute axial periphery and a partial keel, increases gradually upwards in the section. An excellent example of these truncated globorotalias is *G. angulata angulata* (White) which is taken as the index species of this zone, although it continues in the overlying zone. The development of *G. angulata angulata* from the typically rounded form *G. pseudobulloides* (Plummer) through *G. trinidadensis* Bolli and *G. uncinata uncinata* Bolli is clearly documented (Text-fig. 15), and demonstrates the tendency of *Globorotalia* to develop from rounded to truncated forms upwards in the section. On the other hand, *G. angulata angulata* also demonstrates the evolutionary development of the truncated, non-keeled *Globorotalia* into the sharply-keeled ones by the development, in the overlying zone, into *G. velascoensis velascoensis* (Cushman) through *G. angulata abundocamerata* Bolli. This, added to the fact that the first appearance of *G. angulata angulata* coincides with the disappearance of the index species of the underlying zone which represents the lowest Paleocene or the Danian, and that *G. angulata angulata* was never recorded from the type Danian, justifies the position of the *G. angulata* Zone at the Middle of the Paleocene series. From an evolutionary point of view, this zone with truncated *Globorotalia* is regarded as a transitional stage between the underlying rounded *Globorotalia* Zone and the overlying zone with sharply-keeled *Globorotalia*. This is also substantiated by the fact that this intermediate zone is represented by a relatively smaller thickness of strata. However, as its characteristic assemblage of planktonic Foraminifera can not be assigned to either the overlying or the underlying zones, it is advisable to treat it separately. The lower boundary of this zone is marked by the first appearance

of its index species, and its upper boundary is marked by the first appearance of the sharply keeled *Globorotalia* assemblage, typified by *G. velascoensis velascoensis* (Cushman) and *G. pseudomenardii* Bolli.

3. An upper zone characterized by an assemblage of rugose *Globigerina* and sharply-keeled and/or rugose *Globorotalia* species. In this zone, the tendency towards the development of a marginal keel and/or a rugose surface which started with the early representatives of *Globorotalia* in the Lower Paleocene, is fully achieved. At the bottom of this zone the first known sharply-keeled *Globorotalia*, represented by *G. velascoensis velascoensis* (Cushman) and *G. pseudomenardii* Bolli, make their appearance. *G. pseudomenardii* dies out towards the middle but *G. velascoensis velascoensis* continues to the top, where it dies out completely. *Globorotalia velascoensis* with its three subspecies, *G. velascoensis velascoensis*, *G. velascoensis parva*, and *G. velascoensis caucasica*, represent the dominant forms of the zone which is thus known as the *G. velascoensis* Zone. This zone is considered to represent the Upper Paleocene in Mexico, in the Gulf and Atlantic Coastal Plains of the U.S.A., in the Caribbian region, in Southern France, in Italy, in North Africa, in the Middle East, in Pakistan–India–Burma region, in New Zealand and in the U.S.S.R., although the characteristic species are not recorded in the type Upper Paleocene of Western Europe (the Landenian) which is mainly of continental and lagoonal facies. However, as previously mentioned, the sharply keeled *Globorotalia* assemblage of the *G. velascoensis* Zone represents the maximum development of a continuous evolutionary trend which started at the base of the Paleocene, typified by the bio-series : *Globorotalia pseudobulloides*→*G. trinidadensis*→*G. uncinata uncinata*→*G. angulata angulata*→ *G. angulata abundocamerata*→*G. velascoensis velascoensis* (Text fig. 15). This continuous evolutionary sequence is paralleled by similar lineages throughout the Paleocene, and proves that there are three distinct stages in the development of the genus *Globorotalia* : the rounded stage, the truncated stage and the sharply keeled stage. It also justifies consideration of these three stages as divisions within one natural unit, hence the position of the *G. velascoensis* Zone as the Upper Paleocene and the underlying two zones as the Middle and Lower Paleocene respectively. Analysis of previously recorded planktonic Foraminifera in the Paleocene of different parts of the world, shows the existence of these three stages, and thus substantiates the division of the Paleocene proposed here.

The Paleocene–Lower Eocene Boundary

The fact that the Upper Paleocene in its type region is represented by non-marine sediments, and that the planktonic Foraminifera in the type Lower Eocene are hardly known, made it difficult to decide the position of the Paleocene–Lower Eocene boundary with certainty. However, as previously suggested by Bolli (1957*a*, 1959*b*), Loeblich & Tappan (1957*a*, *b*) and Bolli & Cita (1960*a*, *b*), and as reasoned above, this boundary is drawn at the top of the *Globorotalia velascoensis* Zone, although Olsson (1960) included the latter zone within the Lower Eocene. Analysis of the planktonic foraminiferal content of the *G. velascoensis* Zone shows clearly that it has more species in common with the underlying Paleocene zones than with the overlying *G. wilcoxensis* Zone which is here taken to mark the base of the Eocene. Moreover, as mentioned above, the planktonic Foraminifera of the *G. velascoensis* zone constitute, with those of the underlying Paleocene zones, a continuous evolutionary series which unites them as one natural unit. On the other hand, the disappearance of several typical Paleocene forms at the base of the *G. wilcoxensis* Zone and the appearance of new forms and new evolutionary tendencies, clearly distinguishes this zone from the underlying Paleocene. In the *G. wilcoxensis* Zone, a tendency towards reduction in the size of test and increase in the surface rugosity and/or the degree of development of the marginal keel in the genus *Globorotalia*, is clearly documented. As a result the majority of the planktonic Foraminifera in this basal Eocene zone have a highly rugose surface and/or a very well developed marginal keel. In this connection, it is worth noting that the rare planktonic forms recorded by Kaasschieter (1961) from the type Ypresian of Belgium, although misidentified, are highly rugose, as are all the forms recorded by Berggren (1960*a*) from the Ypresian of Denmark and northwestern Germany. Moreover, the planktonic Foraminifera of the *G. wilcoxensis* Zone clearly correlate it with the basal Eocene of Mexico, the Gulf and Atlantic Coastal Plains of the U.S.A., the Caribbean region, Denmark, northwestern Germany, southern France, Italy, North Africa, the Middle East, Pakistan–India–Burma region, New Zealand and the U.S.S.R., where similar planktonic foraminiferal assemblages have been recorded. This is substantiated by the fact that in the sections studied, a flood of *Nummulites*, *Operculina*, *Assilina* and *Discocyclina*, amongst numerous typical Eocene forms, is clearly observed in the *G. wilcoxensis* Zone, while the genus *Nummulites*, represented by rare specimens of the very primitive form *N. deserti* de La Harpe, is alone recorded in the uppermost part of the underlying zone. However, a detailed study of the planktonic Foraminifera in the type Lower Eocene is needed before a definite decision on the position of the Palecoene/Lower Eocene boundary can be reached.

B. THE UPPER CRETACEOUS–LOWER TERTIARY IN EGYPT

The classification of the Upper Cretaceous–Lower Tertiary rocks of Egypt was first attempted by Zittel (1883), who considered the fossiliferous marine succession overlying the Nubia sandstone of the Western Desert Oases to belong collectively to the Danian, which he regarded as the youngest stage of the Cretaceous system. As a result, he assigned the underlying unfossiliferous Nubia sandstone to the Upper Senonian, while he considered the nummulitic limestone beds which cap the succession to be of Lower Libyan (Lower Eocene) age. However, he overlooked the succession of shales between the top of his Danian and the base of the nummulitic limestone, which were later recorded by various authors in the Oases and in other parts of Egypt, and were considered by Beadnell (1905) as passage beds between the Cretaceous and the Tertiary systems. Moreover, Zittel advocated the absolute conformity of the Cretaceous–Tertiary succession in southern Egypt, a concept which, as discussed below, was uncritically followed by most stratigraphers and led to great confusion.

Zittel classified the strata he considered to be Danian in the Western Desert Oases into three distinct rock units which he described from the base upwards as follows :

1. Beds of *Exogyra overwegi* von Buch, (Overwegischichten).
2. Greenish and ashen-grey paper-like shales.
3. Snow-white, well-bedded limestones or earthy chalk with *Ananchytes ovata.*

The fossils collected by Zittel from these three rock units were described by Quass (1902) and Wanner (1902) who confirmed Zittel's classification, assigning all these rock units to the Danian. Moreover, Quass considered Zittel's shale and chalk units as two different facies of the same stratigraphical horizon, which he regarded as the Upper Danian.

Apparently Zittel used the term Danain in a much broader sense than that of the original definition of the term. While no known ammonities or inocerami are recorded to range up into the type Danian, Zittel recorded the genera *Libycoceras*, *Baculites* and *Inoceramus* in his " overwegischichten ", but still included it in the Danian. Probably he was confused by Mayer-Eymar (1872) who had extended the Danian to include the Campanian, the Maestrichtian, and the Danian proper and thus added to the confusion regarding the limits between these stages and sub-stages. However, analysis of Zittel's Danian in the light of the present investigation shows that it includes the Upper Campanian, the Maestrichtian and most of the Paloecene. It also indicates a marked break between the Maestrichtian and the overlying Paleocene strata in spite of Zittel's emphasis on the absolute conformity of the succession. Nevertheless, Zittel's concept and classification of the Danian in Egypt were generally followed by later authors, e.g. Ball (1900), Beadnell (1901, 1905), Oppenheim (1902) and Hume (1911), where the latter included as Danian all the succession of strata between the top of the Campanian and the base of the Lower Eocene.

Blanckenhorn (1900) considered Zittel's " overwegischichten " to belong to the Maestrichtian, which he equated with the Dordonian, Upper Aturian and Lower Danian. Later in 1921, he reconsidered the " overwegschichten " to belong to the Campanian and related the other two divisions to the Danian (which he regarded as the youngest stage of the Senonian), ignoring completely the Maestrichtian. Apparently he followed de Grossouvre (1897, 1901) who had included the Maestrichtian within the Campanian as its uppermost part. However, Fourtau (1904), following Arnaud (1897), considered the Upper Senonian to include the Campanian as its lower horizon and the Maestrichtian as its upper, while he regarded the Danian as a distinct stage, younger than and equal in rank to the Senonian stage. He also considered some fossils of Zittel's " overwegischichten " to belong to the Campanian and reasonably stated that the limit between the Maestrichtian and the Danian in Egypt should be drawn at the top of the highest bed with ammonites.

Beadnell (1905) classified the Upper Cretaceous–Lower Tertiary rocks of the Nile Valley, south of Esna, into Campanian, Danian, Passage beds and Lower Libyan, advocating the absolute conformity of the succesion which was previously emphasized by Zittel (1883). Following the general belief of his time, he ignored the Maestrichtian, probably including it within the Campanian, and considered the Danian as the youngest stage of the Cretaceous system, but he did not state to which system his " Passage beds " belong. Thus he assigned the oyster limestone and the associated bone beds, which directly overlie the Nubia sandstone, to the Campanian, and the overlying succession of shales, marls and chalks to the Danian which he correlated with Zittel's Danian of the Western Desert Oases. He regarded the shales between the top of the Danian and the base of the nummulitic limestones above, (Beadnell's Esna shales), as passage beds between the Cretaceous and the Teritary and referred the overlying nummilitic limestones to the Lower Libyan (Lower Eocene) (see Text-fig. 4).

Hume (1911) classified the same succession as Campanian, Danian and Lower Eocene, including Beadnell's Passage beds within his Danian. He correlated this succession with others in the Western Desert Oases, in Wadi Quena and in northern Sinai. He also used these widely-spaced sections to demonstrate the gradual advance of the Upper Cretaceous sea over the Egyptian territory, invading it from the north-east, depositing limestones in the northern part, sandstones in the south, and shales, marls and chalks in between. The relative distribution of these facies both in space and time clearly marks the gradual invasion of the sea, and was used by Hume as a means for classifying the Upper Cretaceous rocks of Egypt into five main types from the north southwards. He suggested that folding towards the end of Cretaceous times led to the formation of a series of parallel ridges rising from the bottom of the Upper Cretaceous sea as islands or submarine ridges. Along these, erosion took place, while deposition continued in the troughs in between ; hence the existence of unconformities and disconformities between the Cretaceous and the Tertiary systems along these ridges, and continuous depositon in the basins separating them. However, the controversy about the nature of the Cretaceous–Tertiary boundary continued, and the vast concept of Zittel's Danian was followed until the use of Foraminifera modified the old beliefs and introduced new and revolutionary concepts.

On the basis of small Foraminifera, Henson (1938) established two zones in the Upper Cretaceous–Lower Tertiary succession of Palestine and adjoining countries (including Egypt), a lower " *Globotruncana–Guembelina* Zone " of Upper Cretaceous age, and an upper " *Globigerina–Globorotalia* Zone, of transitional character between the Cretaceous and the Tertiary. He regarded this transitional zone as extending from the highest Danian into the early Eocene, and considered the junction between these two zones as " a reasonable approximation of the Cretaceous–Eocene contact ". In other words, he considered the *Globotruncana–Guembelina* Zone to represent the Danian (although the genus *Globotruncana* does not occur in the Danian) and the *Globigerina–Globorotalia* Zone to represent the early Eocene, apparently including the Paleocene. Moreover, he noticed that, even when there is no evidence of a break in sedimentation between the Cretaceous and Eocene systems, the fauna of the transitional zone is not equally developed in the various sections examined, and thus he concluded that an imperceptible gap between the Cretaceous and Eocene systems must exist.

On the other hand, Faris (1947) described the Upper Cretaceous–Lower Tertiary succession in the Taramsa–Tukh area, near Quena, in Upper Egypt, and echoed Zittel (1883) in advocating the absolute conformity of the Cretaceous–Eocene succession everywhere in Upper Egypt. He divided the Taramsa–Tukh section into a lower, Cretaceous part and an upper, Eocene part, and divided the former into Maestrichtian and Danian, but, failing to define the boundary between them, he included both on his chart as Danian. He also considered his Eocene to include the so-called " Montian ? " at its base and Londinian at its top ; but, while in the text he considered his basal white limestone bed with *G.* cf. *velascoensis* as the top of his Danian he included it on the chart at the base of the Eocene. However, analysis of the succession as described by him shows that his Danian includes the Middle and part of the Upper Maestrichtian, as well as most of the Paleocene. His " Montian ? " includes the uppermost Paleocene and the basal Eocene, while his Londinian represents the rest of the Lower Eocene. Moreover, a stratigraphical break between the Maestrichtian and the Paleocene in his section is clearly evident (*cf.* the present study), in spite of his repeated emphasis on the absolute conformity of the succession.

Tromp (1949, 1952), using his quantitative generic method in foraminiferal analysis, noticed a number of micro-faunal differences between the uppermost Cretaceous and the basal Eocene in Egypt, Turkey, and the Middle East in general. Nevertheless, he considered the nature of the contact between these two systems to be gradational and denied the existence of any indications of an erosional hiatus at the Cretaceous–Eocene boundary in the Middle East. However, in agreement with Henson (1938), he placed this boundary at the junction of the *Globotruncana–Guembelina* Zone with the overlying *Globigerina–Globorotalia* Zone, although he considered the top of the former zone to represent the top of the Maestrichian, not the Danian as previously suggested by Henson (1938). Moreover, he stated (1949) that the Cretaceous–Eocene boundary in the Middle East cuts through the so-called Danian and makes the term superfluous. As a result, he suggested that the term should be eliminated at least in the Middle East, and added that " Further evidence suggests that in other countries also the term Danian is useless as an accurate stratigraphic unit and should be abandoned ". He also mentioned that by using the quantitative generic method in forminiferal analysis, he had been able to classify the Senonian of Egypt and of Turkey into three stratigraphical units only, which he tentatively termed the Santonian, Campanian and Maestrichtian.

Nakkady (1949, 1950, 1951*a*, 1952, 1955) studied the Foraminifera of six Upper Cretaceous–Lower Tertiary sections from widely separated areas in Egypt. He concluded that the use of rock units as time-rock units (suggested by Zittel 1883 and adopted by later authors) was very misleading, and thus suggested dropping the rock units and using bio-zones instead. Nakkady established three zones in the Cretaceous–Tertiary transition period of Egypt, a lower *Globotruncana* Zone of Maestrichtian age, an upper *Globorotalia* Zone of Paleocene age, and an intervening Buffer zone, described as distinguished by the complete absence or extreme scarcity of both *Globorotalia* and *Globotruncana*, which he assigned to the Danian. In correlating these six widely spaced sections, Nakkady (1951*a*, chart) showed the existence of great differences in the thickness and the stratigraphical position of his Buffer zone, and in the position of the upper limit of his Maestrichtian *Globotruncana* Zone in the different sections studied. However, no attempt was made to explain this marked variation, and instead of interpreting it in the obvious way, as a marked stratigraphical break, Nakkady emphasized the conformity of the succession and stated (1951*a*) that " The chalk and the overlying Esna shales are two phases of continuous sedimentation representing the last sequence of deposition at the close of the Mesozoic and the advent of the Tertiary ". Moreover, he described the Esna shale fauna as transitional in character, and thus followed Beadnell (1905) in regarding the Esna shales as passage beds between the Cretaceous and the Eocene. Furthermore, despite the discovery of breaks between the Cretaceous and the Tertiary in successions previously described as conformable throughout (e.g. Le Roy 1953), Nakkady did not reconsider his statements. On the contrary, this author (1957, 1959) on one side, and Said & Kenawy (1956) and Said (1960) on the other, started a lengthy argument on the so-called retardation in the appearance of *Globorotalia* species in the various sections studied, and its different implications, but overlooked the fact that this can be explained by the occurrence of breaks of varying magnitude between the Cretaceous and the overlying Tertiary rocks.

Le Roy (1953) described the Upper Cretaceous–Lower Tertiary succession of the Maqfi section, on the northeastern corner of the Farafra Oasis, Western Desert, Egypt, and analysed its small foraminiferal fauna. He did not discuss the Nubia variegated claystones and sandstones which constitute the basal part of the succession, but stated that they may probably be of pre-Maestrichtian age and may be separated from the overlying chalk by an unconformity, interpreted by the abrupt change in lithology between the two formations. Nevertheless, he recognized in the overlying succession two major divisions demarcated by a minor lithological change and a major palaeontological hiatus, a lower chalk unit of Upper Cretaceous (Maestrichtian) age, which he termed " Unit A " and an overlying succession of four rock units (IV, III, II and I) of Lower Tertiary age. He recorded the abrupt faunal change between " Unit A " and " Unit IV " which he interpreted as a probable disconformity and stated that it could logically indicate the Mesozoic–Cainozoic boundary.

Le Roy stressed the difficulty in assigning the Tertiary part of the succession to the Paleocene or the Lower Eocene, and stated that " Until the Egyptian Paleocene is more specifically correlated in terms of the European section, the writer favours allocating Unit IV to the basal Eocene ". However, comparison with the present study proves this " Unit IV " to be of Upper Paleocene age, and substantiates a marked break between the Maestrichtian and the overlying Upper Paleocene. On the other hand, Le Roy recorded a distinct erosional surface between his " Unit IV " and the overlying " Unit III ", and a probable disconformity between the latter and " Unit II ". This drove Nakkady (1957) to interpret " Unit III " as a slipped mass of the nummulitic limestone capping the succession. However, Le Roy considered Units III and II as Lower Eocene, and added that although the age of " Unit I " is open to question, he tentatively assigns it to the Lower Eocene as well.

The same section was discussed by Nakkady (1957) ,where he interpreted Le Roy's Lower Tertiary units as representing the Danian, Montian, Thanetian and Ypresian, advocating the conformity of the succession. On the other hand, Said & Kerdany (1961) described the same succession, confirming Le Roy's previous statement of a major palaeontologic hiatus between the Createaceous and the Tertiary, and assigning Le Roy's Units IV, III and II to the Landenian and his Unit I to the Ypresian. However, analysis of their recorded planktonic Foraminifera shows that their Landenian includes both the uppermost Paleocene and the Lower Eocene. *Globorotalia velascoensis* which characterizes the Upper Paleocene and marks the Paleocene–Lower Eocene boundary by the disappearance of its last survivors, was recorded by Le Roy (1953) as characteristic of his Unit IV only, and its range was slightly extended by Said & Kerdany (1961) to the basal part of Le Roy's Unit II. Nevertheless, they included the whole of Unit II which was stated by them to have a thickness of between 120 and 160 metres, together with the underlying Units III and IV within the Landenian. Correlation with the Esna–Idfu sequence, shows clearly that the part of this succession between the upper limit of *G. velascoensis* and the base of the hard crystalline limestone (Le Roy's Unit I) can be equated with the " Thebes calcareous shale member " of the Esna–Idfu region, which is here considered to be of Lower Eocene age.

Nakkady & Osman (1954) discussed the genus *Globotruncana* in Egypt and its value in stratigraphical correlation, using Nakkady's previous sections and two other sections in western Sinai, the Qabeliat and the Sudr sections. Nevertheless, in correlating the Campanian–Maestrichtian succession of these two relatively close sections, the authors could not establish the same zones. Moreover, the record by Nakkady & Osman of forms such as *Globigerina pseudotriloba*, *G. quadrata*, *G. cretacea* var. *esnehensis* in Cretaceous strata is definitely erroneous, as these forms are only known from the Tertiary. Similarly, their records of *Globotruncana contusa*, *G. caliciformis*, *G. aegyptiaca* var. *duwi* and *G. esnehensis* in the Campanian, and forms such as *Globigerina cretacea* d'Orbigny [=*Globotruncana cretacea* (d'Orbigny)] and its synonym *G. globigerinoides* Brotzen, and *Globigerinella aspera*, in the Maestrichtian, are very much doubted. The former species are restricted to the Maestrichtian, while the latter are not known from this stage.

Youssef & Shinnawi (1954) described the succession in Wadi Sudr area, Western Sinai, Egypt, where they showed the difficulty in sub-dividing the Senonian, the Danian and the overlying Paleocene. Between the top of their Lower Senonian and the base of their Lower Eocene, they described a succession (246·5 metres thick) of limestones, chalky limestones and chalk with a thin shaly intercalation at its base They regarded this succession as Campanian–Maestrichtian–Danian and partly Paleocene, advocating the conformable relationship between the Cretaceous and the Tertiary systems. They recorded some planktonic Foraminifera in their shaly bed which they tentatively considered at the base of the Maestrichtian. Of particular interest are *Globotruncana arca* (Cushman) and *G. arca* var. *esnehensis* Nakkady (=*G. esnehensis*) and *G. aegyptiaca* Nakkady, an assemblage which indicates a Maestrichtian age (probably Middle to Upper Maestrichtian). However, their records of *Globigerina cretacea* d'Orbigny, *G. linaperta* Finlay and *G. quadrata* White are erroneous ; the first, (which is a true *Globotruncana*, not a *Globigerina*) does not extend above the Upper Campanian, the second is known from the Lower Eocene and the third is definitely Paleocene. These forms were probably confused with apparently similar *Rugoglobigerina* and *Hedbergella* species, but nothing can be added until the planktonic Foraminifera of the succession are examined in detail.

Youssef (1954) described the succession in the Gebel Owaina section, as summarized above, attributing it to the Maestrichtian, Danian, Paleocene and Lower Eocene, and advocating the conformity of the succession. However, the present study (see Text-fig. 4) shows that his Danian includes most of the Paleocene, and that his Paleocene includes both the uppermost part of this series and the basal Eocene. Moreover, it indicates a marked break between the Maestrichtian and the overlying Paleocene, in spite of Youssef's statement that the succession is apparently conformable throughout.

Said & Kenawy (1956) described the Foraminifera of the Upper Cretaceous–Lower Tertiary succession of the Nekhl and the Giddi Sections, in northern Siani, Egypt. Following Nakkady (1951*a*), they recognized in the two sections a lower unit of Maestrichtian age, characterized by the abundance of *Globotruncana* and *Guembelina* species, a middle unit, of Danian age, characterized by the absence of *Globotruncana* and by the presence of a flood of *Globigerina* together with certain other benthonic forms, and an upper unit of Paleocene age, characterized, according to them, by the appearance of various species of *Truncorotalia* and *Globorotalia* together with several distinctive benthonic forms. They noted that the limits of these biozones are independent of the lithological boundaries, a fact previously recognized by Nakkady (1951*a*). They also followed Hume (1911) and Shukri (1954) in attributing the varied nature of the Cretaceous–Tertiary boundary in geologically adjacent areas in northern Egypt, to deposition over anticlines and synclines which had previously emerged from the bottom of the Upper Cretaceous sea. These folds were attributed to the Syrian arc movement which began at least as early as the Turonian, and which was intermittently active until late Oligocene time. While erosion took place on the anticlines, deposition continued in the adjacent troughs. With this idea in mind, they tried to analyse the stratigraphical succession in the two sections, believing that one of them, the Nekhl section, lay in the heart of a trough in the late Cretaceous sea, while the other, the Giddi section, lay on the flank of one of the main structural highs of that time. However, when the accepted index fossils for this period, the planktonic Foraminifera, showed the incorrectness of this imaginary position of the two sections, they tried to deprive these forms of their value in stratigraphical zonation and world-wide correlation stating that ". . . . in Egypt, where the bottom topography of the Upper Cretaceous–Lower Tertiary sea was affected by great lateral folding movements, environmental conditions may differ from one place to another rather rapidly, and this makes the use of planktonic species of rather limited value. The only exceptions to this rule seems to be the *Globotruncana* and *Gümbelina* species, which are assumed by many authors to have been planktonic " and added " . . . . we have abandoned the classic and oft-repeated zoning based on the planktonic foraminifera *Globigerina* and *Truncorotalia*. We feel that these forms are facies fossils, which, may have some zoning value but which occur, like their descendants in modern times, only in open and moderately deep seas ". Thus, while at the beginning of their work they followed Nakkady's zonation of the Upper Cretaceous–Lower Tertiary rocks of Egypt into a *Globotruncana–Guembelina* Zone of Maestrichtian age, a *Globigerina* or Buffer Zone of Danian age, and a *Globorotalia* Zone of Paleocene age, they used *Bolivinoides* and *Neoflabellina* for the classification of the succession, and thus confused the correlation between the two sections. Without discussing the disadvantages and mistakes of such a classification (e.g. their record of *Neoflabellina rugosa*, a known Campanian form, in their Upper Maestrichtian, Danian and Paleocene), these authors stated that " These species are, unfortunately, rare in the Egyptian material and may escape notice ". However, other than the undisputed value of *Globorotalia* in Lower Tertiary stratigraphy and correlation, the fallacy of the whole picture presented by Said & Kenawy (1956) is clearly demonstrated by their text-fig. 4. In this text-figure, the parallelism between their *Globotruncana* time surface and their *Truncorotalia* surface, indicates that the folding movement which shaped the strata of the two sections in their present day form, definitely took place after the appearance of the sharply-keeled globorotalias, i.e. at least after the beginning of the Upper Paleocene and not before the deposition of the Maestrichtian as suggested by these authors. Indeed, a similar folding movement which affected the Upper Cretaceous–Lower Tertiary rocks of the Esna–Idfu region is of post-Lower Eocene age. Nevertheless, this does not deny the possibility that the Upper Cretaceous sea bottom was affected in certain regions by intermittent folding movements (which might even have started long before the Upper Cretaceous), as suggested by Hume (1911) and Shukri (1954), and substantiated by deep drilling in the northern part of the Western Desert (see Said 1962). One of the most striking contradictions in Said & Kenawy's discussion is their statement that " The Maestrichtian–Danian boundary is therefore of importance in determining the structural position of the locality from which a section was taken. When this boundary coincides with the lithologic boundary between the chalk and the Esna shale, it indicates a structural low, whereas its occurrence within the Esna shale indicates a structural high in the late Cretaceous sea. This idea is further strengthened by the fact that we find the thinnest Danian, followed immediately by the *Truncorotalia* zone, in the structurally low areas ". Contrary to this conclusion, the present study has shown that the variation in the thickness of the Danian strata, which are generally of the same lithological composition, is mainly due to the occurrence of stratigraphical breaks of varying magnitude between the Maestrichtian and the overlying Paleocene, and that the thinnest Danian occurs in areas which were subjected to more uplift and/or more erosion, not in the structually low areas, as suggested by these authors. On the other hand, correlation with the succession in the Esna–Idfu region shows clearly that their Lower Eocene of the Giddi section is partly of Upper Paleocene age, that their Upper Paleocene of the Nekhl section is definitely Lower Eocene, and that the presence of the Danian in the two sections is to be doubted because of the absence of typical Danian forms such as *Globorotalia compressa* (Plummer), *G. pseudobulloides* (Plummer) *G. trinidadensis* Bolli and *Globigerina daubjergensis* Brönnimann. Moreover, it points to the occurrence of a stratigraphical break between the Maestrichtian and the overlying paleocene, substantiated by the reduced thickness of the shale succession between the top of the Maestrichtian and the first appearance of *G. velascoensis*, especially in the Nekhl section (although their *G. velascoensis* is misidentified).

Hassan (1956) studied the type area of Zittel's " overwegischichten " in the Kharga Oasis, which he considered to be of Maestrichtian age, and divided it into the following three faunal zones :

1. A lower zone (A) with *Isocardia chargensis, Bostrychoceras polyplocum, Nostoceras* sp., *Nautilus desertorum, Baculites anceps, Chlamys mayereymari* and *Trignoarca* cf. *gauldrina.*
2. A middle zone (B) with *Exogyra overwegi, Plicatula instabilis, Plicatula aschersoni, Veniella* (*Roudaireia*) *drui, Cardita libyca* and *Hoplitoplacenticeras awadi.*
3. An upper zone (C) with *Cardita libyca* and no ammonites.

He followed Laffitte (1934, 1939) in considering the lower limit of the Maestrichtian in North Africa to be marked by the appearance of *Orbitoides tissoti, Bostrychoceras polyplocum* and *Libycoceras ismaëli* and thus considered his zone (A) to be of Lower Maestrichtian age. However, as mentioned by Leriche (1927, 1929), Abrard (1931, 1948) and Jeletzky (1951), *Bostrychoceras polyplocum* characterizes the Upper Campanian in its type area, and Hassan's zone (A) should therefore belong to the Upper Campanian and not the Lower Maestrichtian, if his record of *Bostrychoceras polyplocum* is correct.

In his zone (C), Hassan stated that " Not a single ammonite has been found in the third zone which is crowded with *Cardita libyca* ". Nevertheless, he assigned this zone to the Upper Maestrichtian, although in the same paper he mentioned that Fourtau (1904) had clearly reasoned that the limit between the Maestrichtian and the Danian should be drawn at the top of the highest bed with ammonites in the Libyan Desert.

Nakkady (1959) described the same section and assigned the lower part of the succession to the Maestrichtian, the *Cardita* beds and the overlying shale and chalk section to the Danian and the nummulitic limestone above, to the Montian. However, analysis of his recorded planktonic Foraminifera shows that his Danian actually represents the whole Paleocene, while his Montian represents the Lower Eocene. Moreover, a comparison of the succession, as described by both Hassan (1956) and Nakkady (1959), with the sections studied, clearly points to the occurrence of a marked stratigraphical break, in spite of the fact that these authors described the succession as perfectly conformable.

Nakkady (1957) reviewed the biostratigraphy of the Upper Senonian and the Paleocene of Egypt, which he tried to correlate with corresponding units in other parts of the world. He considered the Senonian to include the Coniacian and the Santonian as its lower part, and the Campanian and the Maestrichtian as its upper, and divided the Paleocene into a lower part including the Danian and the Montian, and an upper including the Thanetian and Sparnacian. However, although he only discussed what he described as Campanian, Maestrichtian, Danian and Montian, analysis of his faunal lists shows that his Montian actually represents the Lower Eocene and his Danian, the whole Paleocene. Moreover, comparison of the eight sections correlated by him (Text-fig. 2) with the succession in the Esna–Idfu region, indicates a marked break between the Upper Cretaceous and the overlying Tertiary rocks in each of the described sections, despite the fact that he strongly advocated the conformity of the whole succession.

Youssef (1957) described the Upper Cretaceous–Lower Tertiary succession in the Kosseir area, recognizing the following four formations from the base upwards : the Nubia sandstone, the Kosseir variegated shales, the Duwi formation and the Esna shales. He included the first three formations within the Campanian (although he considered the top part of the last formation to be of basal Maestrichtian age), and regarded the Esna shales as representing most of the Maestrichtian, the Danian (or Dano-Montian) and the Paleocene. He did not discuss the stratigraphical position of the overlying limestone beds, but included them on his columnar section within the Paleocene, and considered the succession to be conformable throughout. He mentioned the difficulty in establishing the lower and upper limits of the Maestrichtian, but following Laffitte (1939) he considered the base of this stage to be marked by the appearance of *Libycoceras ismaēli* Zittel and its associated fauna, which is here considered to be of Upper Campanian age. The succession compares well with that of the Esna–Idfu region, although the phosphate formation is much more developed in the Kossier area. Correlation of the two sections shows that the base of Youssef's Maestrichtian should be included in the Upper Campanian, and the Maestrichtian–Danian boundary should cut somewhere through the 105 metres thick shale bed considered by him to lie at the base of the Danian. This shale bed actually includes the top of the Maestrichtian and most of the Paleocene. Moreover, it is felt, by comparison with the succession in the Esna–Idfu region, that a careful examination of the above-mentioned shale bed may prove the existence of a stratigraphical break marking the Mesozoic–Cainozoic boundary, despite Youssef's emphasis on the conformity of the succession.

Faris & Hassan (1959) described the Upper Cretaceous–Lower Tertiary succession of the Um-El-Huetat section, Safaga area, Red Sea coast, which they divided into seven successive units. They considered the lowest two units (I and II) as Lower Senonian and even older, Unit III as Santonian to Campanian, Units IV and V as Lower and Upper Maestrichtian respectively, Unit VI as Danian to Paleocene and Unit VII as Lower Libyan. However, analysis of the succession as summarized by them shows that the upper part of their Unit VI which they collectively described as " Danian to Paleocene ", is of Lower Eocene age. The " *Eponides lotus* fauna " which was described by Le Roy from the Maqfi section and with which they correlated this part of their succession, is of Lower Eocene age (see p. 37). Again, their description of the underlying zone as characterized by *Aturia* cf. *praeziczac* is very misleading, as the latter species characterizes, in the Luxor section, an horizon equivalent to the " *Eponides lotus* fauna " of the Maqfi section. Moreover, in spite of a marked break in the succession, and the absence of the Lower and Middle Paleocene in the Maqfi section, *Eponides lotus* was found to appear at a vertical distance of about 120 metres from the underlying Maestrichtian surface, while they recorded this species in a lithologically identical succession, at a vertical distance of only 70m. from the top of their Maestrichtian, and advocated the conformity of the succession throughout. However, until the succession is more carefully examined, nothing much can be added, although the Foraminifera of two samples from the Maestrichtian part of the succession (described by Ansary & Fakhr 1958), included some rare planktonic forms. Nevertheless, a probable stratigraphical break between the Maestrichtian and the overlying Paleocene is indicated by the marked reduction in the thickness of the strata assigned to the latter series.

Said (1960) recorded fourteen species of planktonic Foraminifera from what he described as Esna shale and the overlying Thebes formation of the Gebel Gurnah section, at Thebes (on the western bank of the Nile, facing Luxor). He concluded that the " Esna shale " is Landenian in age while the Thebes limestone is Ypresian. Analysis of his described planktonic Foraminifera, and comparison with the present study shows that both the shales and the limestones are of Lower Eocene age. It also indicates that the shaly part of the succession is equivalent to the " Thebes calcareous shale member " of the Gebel Owaina section, which is here equated with the *Globorotalia wilcoxensis* Zone of earliest Eocene age. This throws doubt on the validity of the identification of forms recorded by Said, e.g. *G. velascoensis* (Cushman), *G. imitata* (Subbotina), *G. conicotruncata* (Subbotina) and *Globigerina triloculinoides* Plummer, which are restricted to the Paleocene. However, the possibility that the basal 1 – 5 metres of the succession may be of uppermost Paleocene age is not excluded. Indeed comparison of his figures and descriptions with the original descriptions and figures of the above-mentioned species, and with the specimens described in the present study shows that his forms need to be renamed and re-described in more detail.

Hermina, Ghobrial & Issawi (1961) described the Upper Cretaceous–Lower Tertiary succession of the Dakhla Oasis, Western Desert, Egypt, and in disagreement with Zittel (1883) and Beadnell (1901), they recorded a marked break between the Maestrichtian and the overlying Danian in most of their measured sections. However, they noticed that the gap represented by this break is gradually minimized westwards where they stated that " . . . a monotonous shale section follows above the uppermost zone of the Upper Maestrichtian with possible conformable relationship ".

These authors considered the unfossiliferous Nubia formation to be of uppermost Campanian or Lower Maestrichtian age (being conformably overlain by rocks they regarded as of Lower Maestrichtian age), and classified the overlying strata as Maestrichtian, Danian, Paleocene and Lower Eocene. Moreover, they divided both their Maestrichtian and Danian into lower, middle and upper units, and their Paleocene into Lower and Upper Paleocene. However, it is evident from their description that their divisions were very tentative and hardly based on any correlation with the type or corresponding sections in other parts of the world. Nevertheless, comparison with the succession in the Esna–Idfu region showed that :

1. Their Lower Maestrichtian should be assigned to the Upper Campanian, as both the *Bostrychoceras polyplocum* and the *Inoceramus regularis* faunal assemblages with which they tried to equate their Lower Maestrichtian, are of Upper Campanian age (see " General Discussion " above).
2. Their Middle and Upper Maestrichtian, probably represent the most complete Maestrichtian section as yet known in southern Egypt. The upper zone of their Upper Maestrichtian which they distinguished by the presence of *Trigonoarca gauldrina* and *Cardita dakhlensis*, is missing in the Esna–Idfu region and was reported by them to be missing from most of their measured sections.
3. In spite of the above-mentioned fact, their statement of a possible conformable relationship between the Cretaceous and the Tertiary systems in the western part of the Oasis, still needs further support. Their only argument is the existence of a zone with *Globigerina spp.* and no *Globorotalia* of the *compressa* group on top of the Maestrichtian *Globotruncana* zone. Yet, the same zone is recorded at the base of the type Danian, where a physical break in the succession and a major faunal break are documented.
4. Both their Danian and Paleocene are extremely difficult to correlate, although their *Ostrea hypoptera* Zone which they regarded as Upper Danian, corresponds in the present study to most of the *G. velascoensis* Zone which represents the Upper Paleocene. If this is the case, their Danian should be regarded as representing most of the Paleocene, and the Paleocene–Lower Eocene boundary should cut through their Upper Paleocene. However, a detailed study of the planktonic Foraminifera of this succession is needed to establish a proper correlation, and to reveal the missing zones in the previously described Cretaceous–Tertiary sections.

This rapid review of the most important Upper Cretaceous–Lower Tertiary sections in Egypt summarizes the nature, classification and distribution of these rocks and their varied interpretation by different authors. It also shows the difficulties encountered in the stratigraphical analysis of these strata, and the several problems which were left unsolved. Comparison with the succession in the Esna–Idfu region shows clearly that the boundary between the Campanian and the Maestrichtian could not be decided, that the Maestrichtian could not be defined or classified, that the Mesozoic–Cainozoic boundary could not be traced, that the Danian could not be clearly defined, that the various divisions of the Paleocene were very much confused, and that the Paleocene–Eocene boundary was differently interpreted by different authors.

C. SUMMARY OF THE SUCCESSION

The Upper Cretaceous–Lower Tertiary succession in the Esna–Idfu region is naturally divided into four main lithological units which are easily recognizable in the field and are arranged from the base upwards as follows :

1. A lower arenaceous unit composed mainly of sandstones, and passing into variegated shales at its top through various intercalations of shaly sandstones, sandy shales, shales and clays. The base of this unit is nowhere visible in the region, but can be seen unconformably overlying the basement complex at a distance of about 75 kms. to the east and about 100 kms. to the south. This unit is about 500 m. thick, but a maximum thickness of 80 m. only crops out in the Esna–Idfu region.
2. An alternating succession of broadly extended phosphate lenses (approaching the form of regular beds), marl with flint nodules, chert bands and oyster limestone, which has a maximum thickness of about 10 m.
3. A lutaceous unit about 240 m. thick, composed mainly of shales, but with marly and chalky intercalations.
4. An upper calcareous unit composed of a small thickness of calcareous shales at its base, passing upwards into chalky, marly and siliceous limestones which constitute the main part of this unit. Only the basal 60 m. or so crop out in the Esna–Idfu region, while to the north and west the unit reaches a thickness of about 340 m.

The lowermost sandstone unit, which was commonly referred to as " the Nubian sandstone " was recognized by Youssef (1957), in the Kosseir area, as a formation and was named the " Nubia sandstone ".

Ghorab (1956) considered the variegated shales overlying the Nubia sandstone and underlying the lowermost phosphate bed in the Kosseir area as a separate formation and named it the " Quseir formation ". Youssef (1957) suggested the name " Kossier variegated shales " for the same formation. However, because of the small thickness outcropping of both the sandstones and the shales in the Esna–Idfu region, and because the two facies pass imperceptibly into one another, these variegated shales are here included within the Nubia sandstone, and the two facies are considered as one formation which is here collectively termed " the Nubia sandstone and variegated shale ".

A succession of phosphates, marls and limestones overlies the Nubia sandstone and variegated shale, with a general conformable relationship, except for local thinning out, diastems or even disconformities. This succession, although of a comparatively small thickness (not exceeding 10 m.), has a considerable lateral extent, and forms a sharply distinctive and a conveniently mappable rock unit. Thus it is here considered as a distinct formation and assigned the name " Sibaîya phosphate ". Ghorab

LITHOSTRATIGRAPHICAL UNITS			BIOSTRATIGRAPHICAL UNITS						AGE			
GROUP	FORMATIONS AND MEMBERS		PLANKTONIC FORAMINIFERAL UNITS			MACROFAUNAL UNITS			SUBSTAGE	STAGE	SERIES	SYSTEM
			ASSEMBLAGES	ZONES AND SUBZONES		ASSEMBLAGES	ZONES AND SUBZONES					
LIBYA GROUP	THEBES LIMESTONE AND CALCAREOUS SHALE	THEBES LIMESTONE	VERY RARE PLANKTONIC FORAMINIFERA (Flood of Nummulites Operculina, Assilina, Discocyclina, etc.)			ASSEMBLAGE WITH NO AMMONITES	Lucina thebaica Zone			YPRESIAN	EOCENE	TERTIARY
		THEBES CALCAREOUS SHALE	HIGHLY RUGOSE GLOBIGERINA / HIGHLY RUGOSE AND/OR KEELED GLOBOROTALIA	Globorotalia wilcoxensis Zone			Zone with no macrofauna (except for rare dwarfed forms)					
ESNA GROUP	OWAINA SHALE	UPPER OWAINA SHALE	GLOBIGERINA / SHARPLY-KEELED GLOBOROTALIA	Globorotalia velascoensis Zone	Globorotalia aequa / Globorotalia esnaensis Subzone					LANDENIAN	PALEOCENE	
		MIDDLE OWAINA CHALK			Globorotalia pseudomenardii Subzone		Ostrea hypoptera Zone					
		LOWER OWAINA SHALE	GLOBIGERINA / TRUNCATED GLOBOROTALIA	Globorotalia angulata Zone	Globorotalia pusilla Subzone Globorotalia uncinata Subzone		Caryosmilia granosa Zone			HEERSIAN		
			GLOBIGERINA / ROUNDED GLOBOROTALIA	Globorotalia compressa / Globigerina daubjergensis Zone					UPPER DANIAN	DANIAN		
	SHARAWNA SHALE	UPPER SHARAWNA SHALE	GLOBOTRUNCANA / RUGOGLOBIGERINA / ABATHOMPHALUS / HEDBERGELLA	Globotruncana esnehensis Zone		LIBYCOCERAS / BACULITES ASSEMBLAGE	Pecten (Chlamys) mayereymari Zone	Libycoceras berisensis Subzone	Upper	MAESTRICHTIAN	UPPER CRETACEOUS	CRETACEOUS
		MIDDLE SHARAWNA MARL		Globotruncana gansseri Zone				Pecten (C) mayereymari Subzone	Middle			
		LOWER SHARAWNA SHALE		Globotruncana fornicata Zone				Terebratulina gracilis Subzone	Lower			
NUBIA GROUP	SIBAIYA PHOSPHATE		VERY RARE PLANKTONIC FORAMINIFERA				Lopha villei Zone		CAMPANIAN	SENONIAN		
	NUBIA SANDSTONE AND VARIEGATED SHALE		NO FORAMINIFERA			Zone with no macrofauna (except for rare plant and vertebrate remains)			CAMPANIAN AND ? PRE-CAMPANIAN			

FIG. 5. Summary of the various Litho- and Biostratigraphical units of the Upper Cretaceous–Lower Tertiary succession in the Esna-Idfu Region.

(1956) considered similar phosphate deposits in Kosseir area as a formation and named it " the Duwi formation ", nevertheless the present phosphate deposits cannot be assigned to the same formation, as they are comparatively much reduced in thickness. The " Sibaîya phosphate " either represents a dwarfed " Duwi formation " or only corresponds to a part of that formation. Until the two formations are precisely correlated, it is advisable to treat them separately.

The thick shale succession, which conformably overlies the Sibaîya phosphate formation, and which is conmmoly referred to as the " Esna shales ", was recognized by Ghorab (1956) as a formation which he named the " Esna formation " and divided into three main members from the base upwards as follows : the " Dakhla ash-grey shale member ", the " snow-white *Ananchytes ovata* chalk member ", and the " Kharga paper shale member ". However, the present study shows that this thick shale succession is actually a group of rock units naturally divided into two distinct formations separated by a marked break and a well developed conglomerate. The lower formation is here named " the Sharawna shale ", with its type section in the Wadi El-Sharawna area, it has a thickness of about 120 m., and is proved to be of Maestrichtian age. It includes three main members, a lower shale, a middle marl and an upper shale member, the top part of which is truncated by a disconformity.

The upper formation is here named " the Owaina shale ", with its type section in Gebel Owaina, it also has a thickness of about 120 m. and is proved to be of Paleocene age ; it includes two shale members separated by a middle chalk member. Its lower limit is marked by the disconformity and its upper underlies the " Thebes calcareous shale ".

The uppermost succession of calcerous shale, shaly limestone, and limestone is here assigned to the " Thebes formation ". However, the lower calcareous shale is distinguished from the overlying " Thebes limestone " as a separate member of the same formation and is given the name " Thebes calcareous shale " although it has been wrongly assigned by various authors to the Esna shale.

These different rock units are summarized in Text-figs. 5 and 8, their fossil content is listed in Text-figs. 16 and 17 and their respective ages are discussed below. The detailed lithostratigraphy of the succession and the lateral variation in the various rock units are discussed elsewhere (El-Naggar *in manu.*), and the main sections examined are correlated in Text-fig. 7.

D. DISCUSSION OF THE AGE

(1) THE NUBIA SANDSTONE AND VARIEGATED SHALE FORMATION

The Nubia sandstone and variegated shale could not be assigned a definite age because of its scanty fossil content. However, as the formation is conformably overlain (in places) by the Sibaîya phosphate formation which is here considered as Upper Campanian, and as the upper part of the Nubia formation contains rare vertebrate remains which are identical to those of the overlying Sibaîya formation, this upper part, at least, should be regarded as only slightly older than the overlying

" Sibaîya formation ".[3] Moreover, as no stratigraphical breaks were observed within the part of this formation, outcropping in the Esna–Idfu region, the author is inclined to include the outcropping part of the Nubia formation in the Esna–Idfu region, in the Campanian. However, as there is no direct evidence, the age of this formation is here considered to be Campanian and ? pre-Campanian.

(2) THE SIBAIYA PHOSPHATE FORMATION

Despite the fact that the Sibaîya formation did not yield any identifiable planktonic Foraminifera, and that its macrofauna does not provide a direct means for correlation with the type sections in Europe, it is here considered to belong to the Upper Campanian for the following reasons :

(a) Blanckenhorn (1921) and Hassan (1956) recorded *Bostrychoceras polyplocum* Roemer, an index fossil for the Upper Campanian in its type section and elsewhere, from the same formation in other parts of Egypt, and with a typically similar association of fauna.

(b) The Sibaîya formation is conformably overlain by the " lower Sharawna shale member ", which is characterized by the first appearance of *Terebratulina gracilis* Schlotheim, an index fossil for the base of the Maestrichtian.

Terebratulina gracilis was also recorded from Lower Maestrichtian strata conformably overlying the " *Bosytrchoceras polyplocum* s.l. Zone " in Germany (Schmid, Hiltermann & Koch 1955) ; in Palestine (Parnes 1956) ; in Holland, Belgium and in the Aquitaine Basin of France (Upper Cretaceous Stratigraphic Commission, International Geological Congress ; *in* Reiss 1962 : 4).

(c) Most of the recorded Pelecypod fauna was considered by the various authors (including Coquand, the creator of the Campanian substage) to be mainly of Campanian age, although a few forms may continue into the overlying basal Maestrichtian. On the other hand, the varied vertebrate fauna of the Sibaîya phosphate formation occurs in Europe in strata of Coniacian to Campanian age (e.g. Siegfried 1954, 1956).

(d) The Sibaîya formation is conformably overlain by two successive planktonic foraminiferal zones which are considered, by correlation with similar zones in other parts of the world (Text-figs. 5, 6), to represent the Lower and Middle Maestrichtian respectively.

(e) In spite of its small thickness, the Sibaîya formation, as a chemically formed deposit, represents a relatively long period of time and an enviroment of deposition, completely different from that of the overlying shales.

(f) The Sibaîya phosphate formation can be correlated with similar deposits in the Kharga and Dakhla Oases, Qift and Quene areas, Kosseir and Safaga districts and with corresponding deposits in the Middle East and North Africa which are regarded as Upper Campanian.

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[3] The close similarity of the vertebrate remains in these two formations suggested their inclusion in one group of rock units, here termed the " Nubia group ", and is discussed elsewhere (El-Naggar, *in manu.*).

(3) The Sharawna Shale Formation.

The Sharawna shale formation is considered to be of Maestrichtian age for the following reasons :

(a) It conformably overlies the Upper Campanian " Sibaîya phosphate formation ".

(b) Eleven meters above the base of the formation, a marly band flooded with *Terebratulina gracilis* Schlotheim, *Isocardia* (*Isocardia*) *chargehensis* Mayer-Eymar and *Pecten* (*Chlamys*) *mayereymari* Bullen-Newton, as well as with several other macro- and microfossils, was discovered. *Terebratulina gracilis* marks the base of the type Maestrichtian in Holland, and of the Maestrichtian rocks in Belgium and in the Aquitain Basin of France (the Maestricht-Committee of the Sub-Committee on the Upper Cretaceous Stratigraphic Commission, International Geological Congress ; in Reiss 1962). It also marks the base of the Maestrichtian in Germany (Schmid, Hiltermann & Koch 1955) and in Palestine (Parnes 1956).

(c) The lower part of the Sharawna shale formation i.e. the Lower Sharawna shale member, is flooded with a rich planktonic foraminiferal fauna (Text-figs. 9–11, 16) which substantiates its Lower Maestrichtian age and correlates it with the Lower Maestrichtian in various parts of the world (Text-fig. 6).

This fauna characterises a particular zone which is here termed the *Globotruncana fornicata* Zone. Noteworthy among the species characteristic of this zone are members of the *Globotruncana fornicata* group and most of the members of the *Globotruncana stuarti* group, the last representatives of which mark the Lower Maestrichtian in most parts of the world. (e.g. Cita 1948 ; Tilev 1951, 1952 ; Drooger 1951 ; Bolli 1951, 1957*a* ; Noth 1951 ; Sigal 1952 ; Dalbiez 1955 ; Gandolfi 1955 ; Pozaryski & Witwicka 1956 ; Brönnimann & Brown 1956 ; and Pessagno 1960).

Also of importance in this zone are : *Globotruncana arca*, *G. gagnebini*, *G. fareedi*, *G. havanensis* and *Rugoglobigerina rugosa*, which are known to be restricted to the Maestrichtian in different parts of the world (see Brönnimann & Brown 1956 ; Tilev 1951, 1952 ; Bolli 1957*a* ; Berggren 1962, etc.), as well as *Globotruncana leupoldi*, *G. aegyptiaca aegyptiaca*, *G. tricarinata tricarinata* and *G. ventricosa*, which characterize older strata, but range through the Lower Maestrichtian.

(d) The " Middle Sharawna marl member " is marked by the first appearance of *Globotruncana gansseri ganserri* Bolli at its base, and this, together with its other subspecies, floods the whole unit and the lower part of the overlying shale member, constituting a particular faunal zone, here termed the "*Globotruncana gansseri* zone ". Analysis of the stratigraphical ranges of the various members of this zone, substantiates its Middle Maestrichtian age and correlates it with corresponding strata elsewhere. *Globotruncana gansseri gansseri* Bolli, the index fossil of the zone, was recorded as flooding the Middle Maestrichtian of various parts of the world, with rare occurrence in the upper part of the Lower Maestrichtian and in the basal part of the Upper Maestrichtian (Bolli 1951, 1957*a*, 1959*b* ; Nakkady & Osman 1954 ; Gandolfi 1955 ; Dalbiez 1955 ; Brönnimann & Brown 1956 ; Olsson 1960 ; Pessango 1960 ; and Berggren 1962). This zone is also flooded with forms of definite Maestrichtian age such as *Globotruncana contusa contusa, G. contusa patelliformis, G. arca, G. conica, G. esnehensis, G. fareedi, G. gagnebini, G. lugeoni, G. stuarti parva, G. aegyptiaca aegyptiaca, G. aegyptiaca duwi, G. havanensis, Abathomphalus intermedia, Rugoglobigerina rugosa, R. pustulata, R. pennyi, R. macrocephala, R. loetterli, R. glaessneri, Hedbergella monmouthensis, H. petaloidea, H. mattsoni, H. hessi hessi* and *H. hessi compressiformis.*

Some of these species were recorded from the type Maestrichtian (Hofker 1962*a*), from the Maestrichtian rocks underlying the type Danian (Troelsen 1955 ; Berggren 1962) and from the Maestrichtian rocks of various parts of the world. (See the discussion under each of the above-mentioned species.)

(e) The Upper Sharawna shale member conformably overlies the " Middle Sharawna marl member ", while its top is truncated by a marked stratigraphical break. A conglomerate with reworked Maestrichtian ammonites, gastropods and lamellibranchs, together with a typical Upper Danian fauna, marks this break and indicates the dawn of the Cainozoic era.

Analysis of the planktonic foraminiferal content of the " Upper Sharawna shale member " has proved its Middle to Upper Maestrichtian age. It has also proved that its lower part constitutes the top of the Middle Maestrichtian *G. gansseri* zone, while its upper part constitutes the lower part of the Upper Maestrichtian *G. esnehensis* zone. Worthy of mention in the latter zone are the following species :

Abathomphalus mayaroensis, A. intermedia, Globotruncana contusa contusa, G. contusa patelliformis, G. esnehensis, G. gagnebini, G. aegyptiaca aegyptiaca, G. aegyptiaca duwi, G. mariei, G. havanensis, G. stuarti parva, Rugoglobigerina rugosa, R. rotundata, R. pustulata, R. pennyi, R. macrocephala, Trinitella scotti, Hedbergella monmouthensis, and *H. petaloidea.* These were partly recorded from the Upper Maestrichtian at its type section (Hofker 1962*a*), from the Upper Maestrichtian rocks below the type Danian (Berggren 1962 and Troelsen 1955), and from the same horizon elsewhere (Brönnimann 1952*a* ; Brönnimann & Brown 1956 ; Bolli 1951, 1957*a*, 1959*b* ; Dalbiez 1955 ; Pessango 1960, 1962, etc.). However, the fact that in the succession studied, the Upper Maestrichtian part is represented by a comparatively small thickness of strata (about 13 m. only), and that reworked Upper Maestrichtian macrofossils occur in the conglomeratic band which forms the base of the Upper Danian strata above, clearly indicates that the uppermost Maestrichtian is missing. Thus the upper part of the " Upper Sharawna shale member " corresponds to the lower part of the Upper Maestrichtian only.

The macrofauna of the Sharawna shale formation correlates it with equivalent Maestrichtian strata in Egypt, the Middle East and North Africa (Parnes 1956 ;

Hassan 1956 ; Youssef 1957 ; Hermina, Ghobrial & Issawi 1961). Its planktonic Foraminifera correlate it with the type Maestrichtian (Hofker 1962*a*), with the Maestrichtian rocks below the type Danian (Berggren 1962 and Troelsen 1955) and with the Maestrichtian in various parts of the world (Text-fig. 6). However, the disconformity separating the Maestrichtian Sharawna shale formation from the overlying Paleocene was always overlooked in the past, and the stratigraphical sequence as well as the chronological succession of life in this part of the geological column was never completely understood. As a result, various authors (e.g. Hume 1911, 1912, followed by most stratigraphers) tended to lump the Sharawna shale formation, either partly or completely, together with the overlying Lower Owaina shale member under the term " Lower Esna shales ", and considered these shales with the overlying chalk bed as of Danian age. On the other hand, Nakkady (1959) described as " Lower Esna shale " in the Kharga Oasis, a succession of Paleocene shales which is here considered to be identical with the Lower Owaina shale member.

Thus, it is evident that the classification of the Esna shale into lower and upper units as suggested by Hume (1911, 1912) and followed by various authors is incorrect, and should be replaced by the classification suggested here. Again, it is worth noting that the term Dakhla shale, introduced by Ghorab (1956) as a member of his Esna formation, to substitute for the " Ashen grey paper shales " of some authors, or the " Lower Esna shale " of others, and which was raised to formational rank by Said (1961) is also incorrect. The " Dakhla shale " as originally designated and interpreted in the present study, includes the Maestrichtian " Sharawna shale ", the conglomerate separating it from the overlying Paleocene " Owaina shale ", and the lower part of the latter formation. These varied lithological and palaeontological units which are clearly separated by a marked break, cannot be treated as one formation. Thus the term " Dakhla shale " is here dropped and the classification of the Esna group into a lower " Sharawna shale " formation and an upper " Owaina shale " formation is suggested.

The " Sharawna shale " is equated on lithological and palaeontological grounds with similar successions in both the Dakhla and the Kharga Oases (Western Desert) and in the Kosseir and Safaga areas (Red Sea Coast). It is proved to have a wide geographical extent in Egypt, although it becomes gradually more calcareous when followed northwards until completely replaced by chalk.

(4) THE OWAINA SHALE FORMATION.

This formation is considered to be of Paleocene age, for the following reasons:

(a) It disconformably overlies the Maestrichtian " Sharawna shale ", and underlies the Lower Eocene " Thebes formation ".

(b) Its base is marked by a conglomerate with reworked Maestrichtian, and Danian faunas, and its upper part coincides with the top of the *Globorotalia velascoensis* Zone which is taken to mark the end of the Paleocene in various parts of the world (see Text-fig. 6).

(c) Its basal part contains a rich fauna of the *Globorotalia compressa/Globigerina daubjergensis* Zone which correlates it with the type Danian (Brönnimann 1953 ; Reichel 1953 ; Troelsen 1957 ; Loeblich & Tappan 1957*a*, *b* ; and Berggren 1960*b*, 1962) and with the Danian elsewhere (Bolli 1957*b*, 1959*b*; Loeblich & Tappan 1957*a*, *b* ; Bolli & Cita 1960*a*, *b* ; Olsson 1960 ; Hay 1960 ; Leonov & Alimarina 1961).

The abundance of *Globorotalia compressa* (Plummer) in the Danian part of this succession, which is very much reduced in thickness (maximum of about 17 m. only), clearly proves that it represents the Upper Danian only (see Berggren 1960*b*, 1962), and that both the Lower and Middle Danian are missing.

(d) This Upper Danian part is followed by a zone devoid of both Danian index species and of those characteristic of the Upper Paleocene. This zone is marked by the first appearance of the truncated *Globorotalia* species and by a flood of the *Globorotalia angulata* group. It is here named the *Globorotalia angulata* Zone and is considered, on the basis of its stratigraphical position, to be of Middle Paleocene age.

(e) The middle and upper members of the Owaina shale formation coincide with the *Globorotalia velascoensis* Zone which is of Upper Paleocene age as discussed above. However, it is worth noting that the first appearance of *Globorotalia velascoensis* does not precisely coincide with the base of the intercalated chalk bed (the Middle Owaina chalk member), but occurs slightly below it in a band of calcareous shale with thin chalky bands which is considered transitional to the Middle Owaina chalk member.

(f) The Owaina shale formation is overlain by the *Globorotalia wilcoxensis* Zone of Lower Eocene age (see Text-figs. 5 and 6).

Thus it is evident that the Owaina shale formation is of Paleocene age, that its basal part corresponds to the Upper Danian in its type section and elsewhere, and that its upper part correlates with the known Upper Paleocene in various parts of the world. However, in view of the confusion about the planktonic foraminiferal content of the various stages of the Paleocene (see p. 25 et seq.), the author decided not to use the known Paleocene stage names (e.g. Montian, Thanetian, Landenian, Seelandian, Ilerdian)[4], but to divide the Paleocene into three major divisions, lower, middle and upper, on the basis of its three planktonic foraminiferal zones, as discussed above (see pp. 24–31) and summarized on Text-figs. 5 and 6.

The planktonic Foraminifera of the Owaina shale formation correlates it with known Paleocene sections elsewhere in the world (Text-fig. 6), and its macrofossils clearly relate it to similar successions in Egypt (Zittel 1883 ; Quaas 1902 ; Wanner 1902 ; Oppenheim 1902 ; Hume 1911 ; Cuvillier 1937*a*, *b* ; Youssef 1955, 1957 ; Hassan 1956 ; Hermina *et al.*, 1961. However, the misunderstanding of the true nature of the Cretaceous–Tertiary contact in Upper Egypt introduced by Zittel (1883) and repeated by Faris (1947) has completely confused the identity of the Paleocene in Egypt. The fact that the stratigraphical break was overlooked, led authors to assign the Owaina shale formation either partly or completely to the Danian. It also led, as mentioned above, to the erroneous classification of the Esna shale into a lower and upper member, separated by the middle chalk. As a result, the lower Owaina shale member was lumped together with all or part of the underlying Sharawna shale under the name " Lower Esna shale ". The latter, together with the overlying chalk bed were assigned by most authors to the Danian, while others also included the overlying shale succession in the " Danian ".

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[4] See footnote [2]

Analysis of the various Paleocene successions described by previous authors who wrongly assigned them to the Cretaceous and/or the Tertiary, shows the widespread nature of the Owaina shale formation, the persistence of its lithological units and the great extent of the Paleocene transgression over the Egyptian territory, (which possibly represents the greatest transgression in the geological history of Egypt). It also shows clearly the applicability of the term " Owaina shale " over vast areas in Egypt, although the formation becomes progressively more calcareous towards the north.

(5) THE THEBES LIMESTONE AND CALCAREOUS SHALE FORMATION.

This formation is considered to be of Lower Eocene age for the following reasons:

(a) It conformably overlies the " Upper Owaina shale member " which is proved to be of uppermost Paleocene age.

(b) Its lower member, the " Thebes calcareous shale ", contains a rich planktonic foraminiferal fauna which correlates it with the Lower Eocene in various parts of the world (Text-fig. 6). Among these, *Globorotalia wilcoxensis* Cushman & Ponton is worth mentioning as it is taken as a guide fossil for the Lower Eocene, in spite of its occurrence in the uppermost part of the underlying Paleocene (see discussion under this species). Also of importance in this assemblage is *Globorotalia bollii* (=*Globorotalia rex* of Bolli 1957*b*) which is considered by various authors as the zone marker of the Lower Eocene (see Text-fig. 6).

(c) The lithology and fauna of the " Thebes limestone member " of the Esna–Idfu region correlate it with the " Thebes limestone " in its type section (Delanoue 1868 ; Said 1960) and its equivalents elsewhere, which were generally assigned to the Lower Libyan. Such characteristic lithology and fossil content are almost uniform over a vast extent of the Egyptian territory, constituting a particular rock unit which is generally assigned to the Lower Eocene (Zittel 1883 ; Cuvillier 1930, etc.).

(d) Although washed samples from the " Thebes limestone member " of the Esna–Idfu region did not yield any identifiable planktonic Foraminifera (possibly because of its silicification), samples from the type section at Thebes were recorded by Said (1960) to contain a few planktonic forms. These, although misidentified, support the Lower Eocene age of the type Thebes limestone.

Thus, it is evident that the Thebes limestone and calcareous shale formation is of Lower Eocene age. However, the controversy about the stratigraphical relationship between the Ypresian and Cuisian stages, necessitates the avoidance of the use of these terms in Lower Eocene stratigraphy, until their chronological relationship is clarified.[5] For example, while some authors tended to use the Ypresian followed by the Cuisian within the Lower Eocene, Hottinger & Schaub (1960) used the Cuisian as the Lower Eocene, and Feugueur (1962) equated the Cuisian with the Upper Ypresian.

IV. PALAEONTOLOGY

A. The Macrofauna

Systematic studies of the macrofossils of the Upper Cretaceous–Lower Tertiary rocks of Egypt were carried out by Zittel (1883), Quass (1902), Wanner (1902), Oppenheim (1902), Fourtau (1899–1921), Peron & Fourtau (1904), Stefano (1912–1919), Priem (1914) Greco (1915–1918), Stefanini (1918–1919)[6] and Abbass (1962).

In the present study, macrofossils are used for correlation with similar successions previously zoned on the basis of macrofossils alone. However, most of these fossils are unknown outside the Tethyan region and their ranges have been much disputed in the past. Study of the associated planktonic Foraminifera in the Esna–Idfu region has helped to define the ranges of the macrofossils in terms of the foraminiferal zonation, and has thus cleared up some of the confusion.

One hundred and forty two macrofossil species are identified and their ranges considered (Text-fig. 17). However, no attempt has been made to carry out a systematic study of these macrofossil species which are only listed alphabetically within their respective phyla (Text-fig. 17).

Consideration of the ranges of these macrofossils, has led to the recognition of five major faunal zones and three subzones, in addition to a non-fossiliferous zone at the base, and a zone devoid of macrofossils towards the top of the succession (Text-figs. 5, 8 and 17). These zones and subzones are correlated with the corresponding planktonic foraminiferal zones and subzones in Text-fig. 5 ; they are arranged from the base upwards as follows:

1. A non-fossiliferous zone.
2. The *Lopha villei* Zone.
3. The *Pecten* (*Chlamys*) *mayereymari* Zone.
    (a) The *Terebratulina gracilis* Subzone.
    (b) The *Pecten* (*Chlamys*) *mayereymari* Subzone.
    (c) The *Libycoceras berisensis* Subzone.

~~~~~~~~ Disconformity ~~~~~~~~

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[5] See footnote [2]

[6] See Keldani 1941
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4. The *Caryosmilia garnosa* Zone.
5. The *Ostrea hypoptera* Zone.
6. A non-megafossiliferous zone.
7. The *Lucina thebaica* Zone.

In view of the restricted geographical distribution of most of these macrofossils, the above-mentioned zones may be regarded as of local importance only. Nevertheless, analysis of previously described Upper Cretaceous–Lower Tertiary successions in Egypt, North Africa and the Middle East points to the possible existence of these zones at corresponding horizons all over this region. Some of the index fossils of these zones, e.g., *Lopha villei* and *Libycoceras* spp. (*L. ismaeli* Zittel, *L. chargense* Blanckenhorn and possibly *L. phosphaticus* Awad & Naiem and *L. berisensis* Awad & Naiem) are known to flood corresponding horizons in North Africa, (Laffitte 1934, 1939), while the same species, in addition to *Pecten* (*Chlamys*) *mayereymari* Bullen-Newton and *Terebratulina gracilis* Schlotheim, are recorded in abundance in similar formations in Palestine (Parnes 1956). Thus, although it is understood that these macrofossil zones are not of the world-wide importance of the corresponding planktonic foraminiferal zones, they may be successfully applied in North Africa and the Middle East. The value of these zones is now enhanced by the fact that they have been defined in the light of the corresponding planktonic foraminiferal zonation, and can thus be used in the absence of planktonic Foraminifera.

B. The Planktonic Foraminifera

The Foraminifera of the Upper Cretaceous and Lower Tertiary rocks of Egypt have been dealt with by Nakkady (1949, 1950, 1951*a*, 1952, 1955, 1957, 1959), Nakkady & Osman (1954), Osman (1954, 1955*a*, *b*, *c*), Le Roy (1949, 1953), Omara (1954, 1955, 1956), Said & Kenawy (1956), Said (1960) and Said & Kerdany (1961). However, very little has been published on the planktonic Foraminifera in spite of their abundance, and reliance on the benthonic Foraminifera in stratigraphical zonation has led to a great deal of discrepancy and confusion. In this connection Bolli (1957*a* : 62) stated that " The complete change of the planktonic foraminiferal fauna between the Upper Cretaceous Guayaguayare formation and the Paleocene–Lower Eocene Lizard Springs formation, is not followed by the benthonic Foraminifera . . ., as many as about two-thirds of the benthonic species known in the Upper Cretaceous continue into the Paleocene–Lower Eocene. In cases where only benthonic Foraminifera are present, it may become difficult, therefore, to determine whether a fauna is of Upper Cretaceous or Paleocene age ". The same is true in Egypt, where it has been found essential to establish the stratigraphy of the Upper Cretaceous–Lower Tertiary period on the basis of planktonic Foraminifera which were only briefly dealt with before, and were very much confused and misidentified.

Although Nakkady (1951*a*) was one of the earliest micropalaeontologists to emphasize the value of planktonic Foraminifera in the zonation of the Cretaceous–Tertiary transition period, he only discussed them very briefly in his study on the Foraminifera of the Esna shale. Nakkady (1950, 1951*a*) recorded the occurrence of the following planktonic Foraminifera from the Maestrichtian–Lower Eocene

succession of six widely-separated sections in Egypt : *Globotruncana aegyptiaca* Nakkady, *G. aegyptiaca* var. *duwi* Nakkady, *G. aegyptiaca* var. *I.* Nakkady, *G. arca* (Cushman), *G. arca* (Cushman) var. *esnehensis* Nakkady, *G. cretacea* Cushman, *G. pseudocretacea* Nakkady ; *Globigerina bulloides* d'Orbigny, *G. cretacea* d'Orbigny, *G. cretacea d'Orbigny* var. *esnehensis* Nakkady, *G. linaperta* Finlay, *G. quadrata* White ; *Globorotalia colligera* (Schwager), *G. colligera* (Schwager) var.*crassaformis* (Galloway & Wissler), *G. crassata* (Cushman) var. *aequa* Cushman & Reuz, *G. deceptoria* (Schwager), *G. simulatilis* (Schwager), and *G. velascoensis* (Cushman).

However, examination of his specimens in the British Museum (Natural History), London, showed clearly that:

1. *G. aegyptiaca* var. I is an entirely single-keeled form which belongs to the *Globotruncana gansseri* group.
2. Typical forms of *Globotruncana stuarti stuarti* (de Lapparent) were included within his *G. arca* (Cushman), and thus the former species was not recorded in spite of its abundance in his material and in the Egyptian Maestrichtain rocks in general.
3. *G. arca* var. *esnehensis* is a distinct species from *G. arca* (Cushman) as realized by Nakkady & Osman (1954), and is thus treated separately.
4. Specimens of *G. cretacea* Cushman actually belong to Globotruncana *stuarti stuartiformis* Dalbiez, *G. gagnebini* Tilev, and *G. aegyptiaca aegyptiaca* Nakkady.
5. *G. pseudocretacea* sp. nov. is probably *Globotruncana gagnebini* Tilev.
6. *G. bulloides* d'Orbigny includes some forms related to *Globigerina bacuana* Khalilov and others, which though indeterminable, are completely different from the form of d'Orbigny.
7. Forms described as *G. cretacea* d'Orbigny are actually *Globorotalia trinidadensis* Bolli *G. compressa* (Plummer) and *G.* cf. *pseudobulloides* (Plummer). The form described by d'Orbigny is a true *Globotruncana*, not a *Globigerina*, and does not cross the Campanian–Maestrichtian boundary.
8. The holotype of *G. cretacea* var. *esnehensis* is actually *Globigerina mckannai* White, while the paratype is a transitional stage between *Globorotalia pseudobulloides* (Plummer) and *G. trinidadensis* Bolli.
9. *G. linaperta* Finlay is *Globigerina triloculinoides* Plummer.
10. *Globigerina quadrata* White includes *Globorotalia irrorata* Loeblich & Tappan, *G. tribulosa* Loeblich & Tappan, *Globigerina triloculinoides* Plummer, besides *Globorotalia quadrata* (White).
11. Specimens of *G. colligera* (Schwager) belong to *Globorotalia* cf. *subbotinae* Morozova, *G.* cf. *aequa* Cushman & Renz, and *G.* cf. *wilcoxensis* Cushman & Ponton. The form described by Schwager was recorded from younger strata and is not well known. Until the holotype is refigured and redescribed in more detail, it is not really known what is meant by *G. colligera* (Schwager).

12. *G. colligera* (Schwager) var. *crassaformis* (Galloway & Wissler) is *G. wilcoxensis* Cushman & Ponton.

13. *G. crassata* var. *aequa* Cushman & Renz includes *Globorotalia rex* Martin, *G. aequa* Cushman & Renz and other unknown forms.

14. *G. deceptoria* (Schwager) includes various forms of *Globigerina* and *Globorotalia* e.g. *Globorotalia aequa* Cushman & Renz, *G. wilcoxensis* Cushman & Ponton, and *G. whitei* Weiss ; *Globigerina stonei* Weiss, and *G. valascoensis* Cushman.

15. *G. simulatilis* (Schwager) includes *Globorotalia rex* Martin, *G. occlusa* Loeblich & Tappan, *G. velascoensis parva* Rey, *G.* cf. *pseudoscitula* Glaessner, *G. emilei* sp. nov., and *G.* cf. *angulata abundocamerata* Bolli. Again, *G. simulatilis* was recorded from younger strata, and its holotype needs to be redrawn and redescribed in more detail.

16. *G. velascoensis* (Cushman) includes *G. velascoensis velascoensis* (Cushman), *G.* cf. *angulata angulata* (White), *G.* cf. *angulata abundocamerata* Bolli, *G.* cf. *pseudoscitula* Glaessner, and *G.* cf. *occlusa* Loeblich & Tappan.

Nevertheless, on the basis of these few planktonic forms, Nakkady established three biozones in the Mesozoic–Cainozoic transition beds of Egypt : a *Globotruncana* Zone of Maestrichtian age, a *Globorotalia* Zone of Paleocene age and an intervening Buffer Zone of Danian age, distinguished by the complete absence or extreme scarcity of both *Globorotalia* and *Globotruncana*.

Nakkady's pioneering attempt was mainly based on genera, and as the planktonic Foraminifera are known to exhibit an abrupt change in their generic composition at the Cretaceous–Tertiary boundary all over the world, his Maestrichtian–Danian boundary was correctly drawn. However, he neither recognized the Tertiary character of the Danian fauna, nor the obvious stratigraphical break between the Upper Cretaceous and the basal Tertiary, which can be easily seen on his chart (1951*a*), where his Buffer zone was shown to vary greatly in thickness. Moreover, in his later studies, Nakkady confused the limits between the various stages of the Paleocene and between the Paleocene and the overlying Eocene. Nevertheless, his faunal sequence (a *Globotruncana* Zone, followed by a Buffer or *Globigerina* Zone and a *Globorotalia* Zone, for the Maestrichtian, Danian and Paleocene respectively) has since been observed in many parts of the world and has been used as a basis for the precise zonation of the Cretaceous–Tertiary succession.

Nakkady (1959) recorded the following planktonic Foraminifera from what he considered as Maestrichtian–Montian of the Um Elghanayem section, Kharga Oasis, Egypt : *Globotruncana aegyptiaca* Nakkady, *G. quadrata* Nakkady & Osman ; *Globorotalia angulata* (White), *G. crassata* var. *aequa* Cushman & Renz, *G. deceptoria* (Schwager), *G. pseudomenardii* Bolli, *G. quadrata* Nakkady & Talaat, *G. simulatilis* (Schwager), *G. velascoensis* (Cushman) ; *Globigerina esnaensis* Le Roy, *G. mckannai* White, *G. pseudobulloides* Plummer, *G. quadrata* White, and *G. triloculinoides*

Plummer. Although he did not figure all his forms, analysis of his figures and descriptions showed that:

1. *G. angulata* (White) probably belongs to *Globorotalia occlusa* Loeblich & Tappan, while *G. quadrata* Nakkady & Talaat belongs to *Globorotalia angulata angulata* (White).
2. *G. simulatilis* (Schwager) is probably *Globorotalia acuta* Toulmin.
3. *G. velascoensis* (Cushman) is probably *G. angulata abundocamerata* Bolli.
4. *G. pseudobulloides* Plummer is probably a transitional stage between *Globorotalia trinidadensis* Bolli and *Globorotalia pseudobulloides* (Plummer).
5. *G. quadrata* White is probably *Globorotalia pseudobulloides* (Plummer), and his *G. triloculinoides* Plummer is *Globigerina triloculinoides parva* subsp. nov.

   Moreover, his record of *Globigerina quadrata* White and *G. triloculinoides* Plummer throughout the Upper Cretaceous–basal Tertiary succession points to the possibility that he had lumped apparently similar *Rugoglobigerina* and *Hedbergella* forms with these species and thus extended their ranges.

Nakkady & Osman (1954) briefly discussed the genus *Globotruncana* in Egypt and its value in stratigraphical zonation, basing their discussion on the Maestrichtian sections, previously studied by Nakkady (1949, 1950, 1951*a*, 1952) and on the Campanian–Maestrichtian of Qabeliat and Sudr sections, western Sinai. These authors described seventeen species and four varieties of *Globotruncana*, most of which were new, but, unfortunately, their descriptions are very short and their figures very poor. These forms were cited as follows : *Globotruncana aegyptiaca* Nakkady, *G. aegyptiaca* var. *duwi* Nakkady, *G. aegyptiaca* var. *I.* Nakkady, *G. ansarii* Nakkady & Osman, *G. caliciformis* (de Lapparent), *G. contusa* (Cushman), *G. cretacea* Cushman, *G. esnehensis* Nakkady & Osman, *G. gansseri* Bolli, *G. globigerinoides* Brotzen, *G. lapparenti* Brotzen, *G. pooleyi* Nakkady & Osman, *G. pseudofornicata* Nakkady & Osman, *G. qabeliatensis* Nakkady & Osman, *G. quadrata* Nakkady & Osman, *G. quadrata* var. *plata* Nakkady & Osman, *G. rosetta* (Carsey), *G. sudrensis* Nakkady & Osman, *G. sudrensis* var. *parallela* Nakkady & Osman, *G. torensis* Nakkady & Osman, and *G. ventricosa* White.

The holotypes of these forms need to be re-examined, refigured, and redescribed in more detail so that their true identities can be established, and their relationships to previously described species decided.

Le Roy (1953) recorded the following planktonic Foraminifera from the Maestrichtian–Lower Eocene succession of the Maqfi section, Farafra Oasis, Egypt : *Globotruncna canaliculata* (Reuss) ; *Globigerina esnaensis* Le Roy, *G. pseudotriloba* White, *G. subcretacea* Lomnicki ; *Globorotalia membranacea* (Ehrenberg), *G. simulatilis* (Schwager) and *G. velascoensis* (Cushman).

Analysis of his descriptions and figures showed that:

1. *G. canaliculata* (Reuss) is most probably *Globotruncana arca* (Cushman).
2. *G. esnaensis* Le Roy is a *Globorotalia*.

3. *G. pseudotriloba* White is probably *Globigerina linaperta* Finlay.
4. Apparently he had included under *G. subcretacea* Lomnicki several *Hedbergella, Globigerinelloides, Rugoglobigerina, Globigerina and Globorotalia* species, thus extending its range from the Maestrichtian to the Lower Eocene. His figured specimen is probably a species of *Hedbergella* or *Globigerinelloides*, but the lack of a side view and the brief description make an accurate determination impossible.
5. *G. membranacea* (Ehrenberg) probably belongs to *Globorotalia emilei* sp. nov. while *G. simulatilis* (Schwager) should be assigned to *Globorotalia rex* Martin, and *G. velascoensis* (Cushman) to *G. velascoensis velascoensis* (Cushman).

Said & Kenawy (1956) recorded the following planktonic Foraminifera from the Maestrichtian–Lower Eocene succession of the Giddi and the Nekhl sections, northern Sinai, Egypt : *Globotruncana aegyptiaca* Nakkady, *G. caliciformis* Vogler, *G. conica* White, *G. esnehensis* Nakkady, *G. gansseri* Bolli, *G. lapparenti lapparenti* Brotzen, *G. lapparenti tricarinata* (Quereau), *G. mayaroensis* Bolli, *G. intermedia* Bolli, *G. stuarti* de Lapparent; *Rugoglobigerina* " *cretacea* Cushman " of Bermudez 1952, *R. esnehensis* (Nakkady) ; *Globigerina bulloides* d'Orbigny, *G. linaperta* Finlay, *G. pseudotriloba* White, *G. subcretacea* Lomnicki ; *Globorotalia membranacea* (Ehrenberg), *Truncorotalia colligera* (Schwager), *T. crassata aequa* (Cushman & Renz), *T. esnaensis* (Le Roy), *T. simulatilis* (Schwager), *T. spinulosa* (Cushman), *T. velascoensis* (Cushman), and *T. wilcoxensis* (Cushman & Ponton).

Examination of their figures and very brief descriptions showed that :

1. *G. aegyptiaca* Nakkady is an entirely single-keeled form which should be assigned to *Globotruncana stuarti parva* Gaudolfi.
2. *G. caliciformis* (de Lapparent) (not Vogler), *G. intermedia* Bolli, *G. stuarti* (de Lapparent) and *G. esnehensis* Nakkady are all the same species and should be assigned to *Globotruncana esnehensis* Nakkady & Osman.
3. *G. gansseri* Bolli, *G. lapparenti tricarinata* (Quereau), *R. esnehensis* (Nakkady), *G. cretacea* Lomnicki, *G. membranacea* (Ehrenberg), *T. esnaensis* (Le Roy) and *T. spinulosa* (Cushman) are doubtful forms.
4. *G. lapparenti lapparenti* Brotzen probably belongs to *Abathomphalus mayaroensis* (Bolli) as does *G. mayaroensis* Bolli.
5. *Rugoglobigerina* " *cretacea* Cushman " of Bermudez, is possibly *Globorotalia quadrata* (White).
6. *Globigerina bulloides* d'Orbigny is possibly *Globorotalia pseudobulloides* (Plummer), and both their *G. linaperta* Finlay, and *G. pseudotriloba* White probably belong to *G. triloculinoides* Plummer.
7. *T. colligera* (Schwager) probably belongs to *Globorotalia angulata abundocamerata* Bolli. Schwager's form was recorded from younger strata, and the holotype of this species needs to be redrawn and redescribed as mentioned above.
8. *T. crassata aequa* (Cushman & Renz) and *T. wilcoxensis* (Cushman & Ponton) probably belong to *Globorotalia aragonensis* Nuttall.

9. *T. esnaensis* (Le Roy) probably belongs to *Globorotalia whitei* Wiess.
10. Both their *T. simulatilis* (Schwager) and *T. spinulosa* (Cushman) probably belong to *Globorotalia bollii* sp. nov., and their *T. velascoensis* (Cushman) is probably *Globorotalia angulata angulata* (White) or a transitional form between it and *G. angulata abundocamerata* Bolli.

Said (1960) recorded the occurrence of three species of *Globigerina*, nine species of *Globorotalia*, and two species of *Hastigerina* in the shale and limestone succession of the Gebel Gurnah section, Luxor, which he regarded as Landenian–Ypresian in age. Again, practically all the species were misidentified and thus the stratigraphy was not correctly interpreted. Analysis of his description and figures showed that :

1. *Globigerina eocaena* Gümbel probably belongs to *Globigerina turgida* Finlay.
2. *Globigerina inaequispira* Subbotina probably belongs to *Globigerina pseudoeocaena* Subbotina.
3. *Globigerina triloculinoides* Plummer does not belong to this species, but may be one of its descendants.
4. *Globorotalia conicotruncata* Subbotina is a doubtful form ; Subbotina's species is a junior synonym of *Globorotalia angulata* (White), while his figures are different.
5. *Globorotalia imitata* Subbotina is a doubtful form ; it is different from Subbotina's original description and figures, and from hypotypes of *G. imitata* recorded in the present work.
6. *Globorotalia interposita* Subbotina probably belongs to *Globigerina soldadoensis* Brönnimann.
7. *Globorotalia pentacamerata* (Subbotina) is probably *Globigerina mckannai* White.
8. *Globorotalia planoconica* Subbotina is not a *Globorotalia* but may be referable to the genus *Globanomalina* [?*Globanomalina eocenica* (Berggren)] as are his *Hastigerina aspera* (Ehrenberg) and *Hastigerina micra* (Cole). Ehrenberg's original form most probably belongs to the genus *Globigerinelloides*, and is not recorded from strata younger than Upper Campanian.
9. *Globorotalia pseudotopilensis* (Subbotina) is probably *Globorotalia esnaensis* (Le Roy).
10. *Globorotalia simulatilis* (Schwager) is probably *Globorotalia subbotinae* Morozova.
11. *Globorotalia thebaica* Said is a junior synonym of *Globorotalia prolata* Bolli.
12. *Globorotalia velascoensis* (Cushman) is possibly *Globorotalia formosa formosa* Bolli.

Said & Kerdany (1961) described the following planktonic Foraminifera from the Maestrichtian–Lower Eocene succession of the Ain Maqfi section, Farafra Oasis, Egypt : *Globotruncana arca* (Cushman), *G. cretacea* Cushman, *G. esnehensis* Nakkady, *G. gansseri* Bolli, *G. rosetta* (Carsey) ; *Rugoglobigerina* sp. cf. *R. jerseyensis* Olsson, *R. reicheli pustulata* Bronnimann ; *Globigerina eocaena* Gümbel, *G.* sp. cf. *G. quadrata* White, *G. triloculinoides* Plummer ; *Globorotalia angulata abundocamerata* Bolli, *G. colligera* (Schwager), *G. convexa* Subbotina, *G. esnaensis* (Le Roy), *G. imitata*

Subbotina, *G. pentacamerata* Subbotina, *G. pseudomenardii* Bolli, *G. pseudoscitula* Glaessner, *G. simulatilis* (Schwager), *G. triplex* (Subbotina), *G. varianta* (Subbotina), and *G. velascoensis* (Cushman).

Analysis of their descriptions and figures showed that:

1. *G. arca* (Cushman) is probably *Globotruncana gagnebini* Tilev.
2. *G. gansseri* Bolli is possibly *Globotruncana rosetta rosetta* (Carsey).
3. *G. rosetta* (Carsey) is *Globotrunacna stuarti stuarti* (de Lapparent).
4. *G. eocaena* Gümbel is apparently *Globigerina turgida* Finlay.
5. *G. convexa* Subbotina is most probably *Globorotalia angulata abundocamerata* Bolli, while the figure described by them under the latter name is a doubtful form which is completely different from Bolli's original description and figures.
6. *G. pentacamerata* Subbotina is *Globigerina mckannai* White.
7. *G. simulatilis* (Schwager) probably belongs to *Globorotalia occlusa* Loeblich & Tappan.
8. *G. triplex* (Subbotina) is probably *Globorotalia loeblichi* sp. nov.
9. *G. varianta* (Subbotina) is possibly *Globorotalia pseudobulloides* (Plummer) while their *G. valescoensis* (Cushman) should be assigned to *Globorotalia velascoensis velascoensis* (Cushman).
10. *Rugoglobigerina reicheli pustulata* is probably *Rugoglobigerina rugosa* (Plummer), while their *R. sp.* cf. *R. jerseyensis* Olsson, their *G. cretacea* Cushman, *Globorotalia imitata* Subbotina, *G. pseudoscitula* Glaessner, *G. colligera* Schwager, and *Globigerina triloculinoides* Plummer, are doubtful forms.

In the present study, the rich planktonic foraminiferal fauna of the Upper Cretaceous–Lower Tertiary sections provided the only means for precise zonation and inter-regional correlation. The short ranges of most species and their wide geographical distribution points to their great stratigraphical value. However, as is indicated above, previous misidentifications, misinterpretations of stratigraphical ranges, over-brief specific descriptions, crude figures, the abundance of synonyms and homonyms, and the divergent views held by authors on various important taxonomic problems have all helped to mask the value of many species of planktonic Foraminifera in stratigraphical zonation and world correlation, and have filled the literature with an overwhelming amount of confused data.

Although studies aimed at clarifying the identity and establishing the true stratigraphical ranges of various planktonic species have already been made by Cita (1948), Tilev (1951, 1952), Bolli (1951, 1957*a*, *b*), Bolli, Loeblich & Tappan (1957), Subbotina (1953), Gandolfi (1955), Brönnimann & Brown (1956), Loeblich & Tappan (1957*a*), Bolli & Cita (1960*b*), Berggren (1960*a*, 1962), Pessagno (1960, 1962), and Barr (1962), many problems were left unsolved and a new critical study was badly needed. Thus, this part of the work is mainly devoted to a study of the most important members of the recorded planktonic Foraminifera. Each species is treated in detail. Full synonymies with figures and descriptions, to the end of August, 1963, have been compiled (El-Naggar 1963), but, with a few exceptions, only the correct identifications are listed here. References without figures and descriptions are also discussed whenever necessary and the confusion surrounding the species is explained in detail wherever possible.

Species of *Globotruncana*, *Globorotalia* and *Globigerina* are described and figured in detail except for a few that are very rare. Species of *Abathomphalus*, *Rugoglobigerina*, *Trinitella* and *Hedbergella* are only listed and will be dealt with in detail in a future publication, together with other planktonic Foraminifera such as *Globigerinelloides*, *Pseudotextularia*, *Pseudoguembelina*, *Guembelina*, *Planoglobulina*, *Racemiguembelina* and *Heterohelix*. Consideration of the ranges of these planktonic Foraminifera has led to the recognition of seven faunal zones and four subzones ; in addition, three other zones, which are either devoid of planktonic Foraminifera, or contain rare indeterminable forms, have also been recognised. (Text-figs 5 and 6). These zones and subzones are correlated with the corresponding macrofossil zones and subzones (Text-fig. 5), and with various planktonic foraminiferal zones in other parts of the world (Text-fig. 6), they are briefly discussed below and are from the base upwards, as follows:

1. A non-fossiliferous zone.
2. A zone with rare indeterminable planktonic Foraminifera.
3. The *Globotruncana fornicata* Zone.
4. The *Globotruncana gansseri* Zone.
5. The *Globotruncana esnehensis* Zone.

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6. The *Globorotalia compressa*/*Globigerina daubjergensis* Zone.
7. The *Globorotalia angulata* Zone.
    a. The *Globorotalia uncinata* Subzone.
    b. The *Globorotalia pusilla* Subzone.
8. The *Globorotalia velascoensis* Zone.
    a. The *Globorotalia pseudomenardii* Subzone.
    b. The *Globorotalia aequa* / *Globorotalia esnaensis* Subzone.
9. The *Globorotalia wilcoxensis* Zone.
10. A zone with indeterminable planktonic Foraminifera.

1. A NON-FOSSILIFEROUS ZONE.

This zone coincides with the Nubia sandstone and variegated shale formation which is mostly devoid of fossils except for rare plant and vertebrate remains. Several samples were washed for foraminiferal investigation, but no Foraminifera were observed.

2. A ZONE WITH RARE INDETERMINABLE PLANKTONIC FORAMINIFERA.

This zone coincides with the Sibaîya phosphate formation which contains extremely minute forms of Foraminifera, that could only be seen in thin section and thus could not be identified with certainty.

3. THE *Globotruncana fornicata* ZONE.

This represents the lowest recognized planktonic foraminiferal zone in the succes-

AGE				PLANKTONIC FORAMINIFERAL ZONATIONS									
SYSTEM	SERIES	STAGE	SUBSTAGE	PRESENT STUDY NILE VALLEY, EGYPT	SUBBOTINA (1953, 1960) THE CAUCASUS, U.S.S.R.	DALBIEZ (1955) TUNISIA	BOLLI (1957a, b, 1959) TRINIDAD	LOEBLICH & TAPPAN (1957a, b) Gulf and Atlantic Coastal Plains, U.S.A.	OLSSON (1960) New Jersey Coastal Plain, U.S.A.	HAY (1960) Tampico Embayment, MEXICO	PESSAGNO (1960, 1962) PUERTO RICO	BOLLI & CITA (1960a, b) Paderno d'Adda Section ITALY	LEONOV & ALIMARINA (1961) The Caucasus U.S.S.R.
TERTIARY	EOCENE	LOWER EOCENE (YPRESIAN)		Globorotalia wilcoxensis zone	b & c (Zone of compressed globorotaliids) c G. margino-dentata subzone		*Globorotalia rex zone*					Globorotalia rex zone	G. proenartanensis zone
	PALEOCENE	UPPER PALEOCENE (LANDENIAN)		Globorotalia velascoensis zone: Globorotalia/ aequa Globorotalia/ esnaensis subzone Globorotalia pseudomenardii subzone	b G. crassata/ A. intermedia subzone ?		*Globorotalia velascoensis zone* *Globorotalia pseudomenardii zone*	? rex zone velascoensis/acuta/ spiralis subzone angulata zone	? Globorotalia angulata zone Globorotalia velascoensis/ Globorotalia acuta/ Globigerina spiralis subzone	Globorotalia velascoensis zone Globorotalia pseudomenardii zone		Globorotalia velcascoensis zone Globorotalia pseudomenardii zone	G. conicotruncata/ G. tadjikistanensis zone G. subsphaerica subzone ? G. tadjikistanensis subzone
		MIDDLE PALEOCENE (HEERSIAN)		Globorotalia angulata zone: Globorotalia pusilla subzone Globorotalia uncinata subzone	a (Zone of rotaliid-like globorotaliids) G. inconstans subzone		*Globorotalia pusilla zone* *Globorotalia uncinata zone*	pseudobulloides subzone	Globorotalia pseudobulloides subzone	Globigerina zone Globorotalia uncinata subzone		Globorotalia pusilla pusilla zone Globorotalia uncinata zone	G. inconstans /G. angulata zone G. angulata subzone G. inconstans subzone
		LOWER PALEOCENE (DANIAN)		Globorotalia compressa/ Globigerina daubjergensis zone (	G. trivialis subzone ?		*Globorotalia trinidadensis zone* *Rzehakina epigona zonule*	compressa/daubjergensis zone ?	Globorotalia compressa/ Globigerinoides daubjergensis zone ?	Globigerinoides daubjergensis subzone		Globorotalia trinidadensis /Globigerina daubjergensis zone	G. pseudobulloides/ G. daubjergensis zone
CRETACEOUS	UPPER CRETACEOUS	MAASTRICHTIAN	UPPER MAESTRICHTIAN	Globotruncana esnehensis zone		*Globotruncana contusa zone*	Abathomphalus mayaroensis zone		Rugoglobigerina jerseyensis/ Hedbergella monmouthensis zone	Abathomphalus mayaroensis zone	Globotruncana contusa/ stuarti assemblage zone Abathomphalus mayaroensis subzone	Abathomphalus mayaroensis zone	
			MIDDLE MAESTRICHTIAN	Globotruncana gansseri zone			Globotruncana gansseri zone				Globotruncana gansseri subzone		
			LOWER MAESTRICHTIAN	Globotruncana fornicata zone		Globotruncana arca zone	Globotruncana lapparenti tricarinata zone				Globotruncana fornicata/ lapparenti/ stuarti assemblage zone Rugotruncana tilevi subzone		

FIG. 6. Correlation of the Planktonic Foraminiferal Zones in the Upper Cretaceous–Lower Tertiary succession of the Esna-Idfu Region, Nile Valley, with the corresponding zones in other parts of the World.

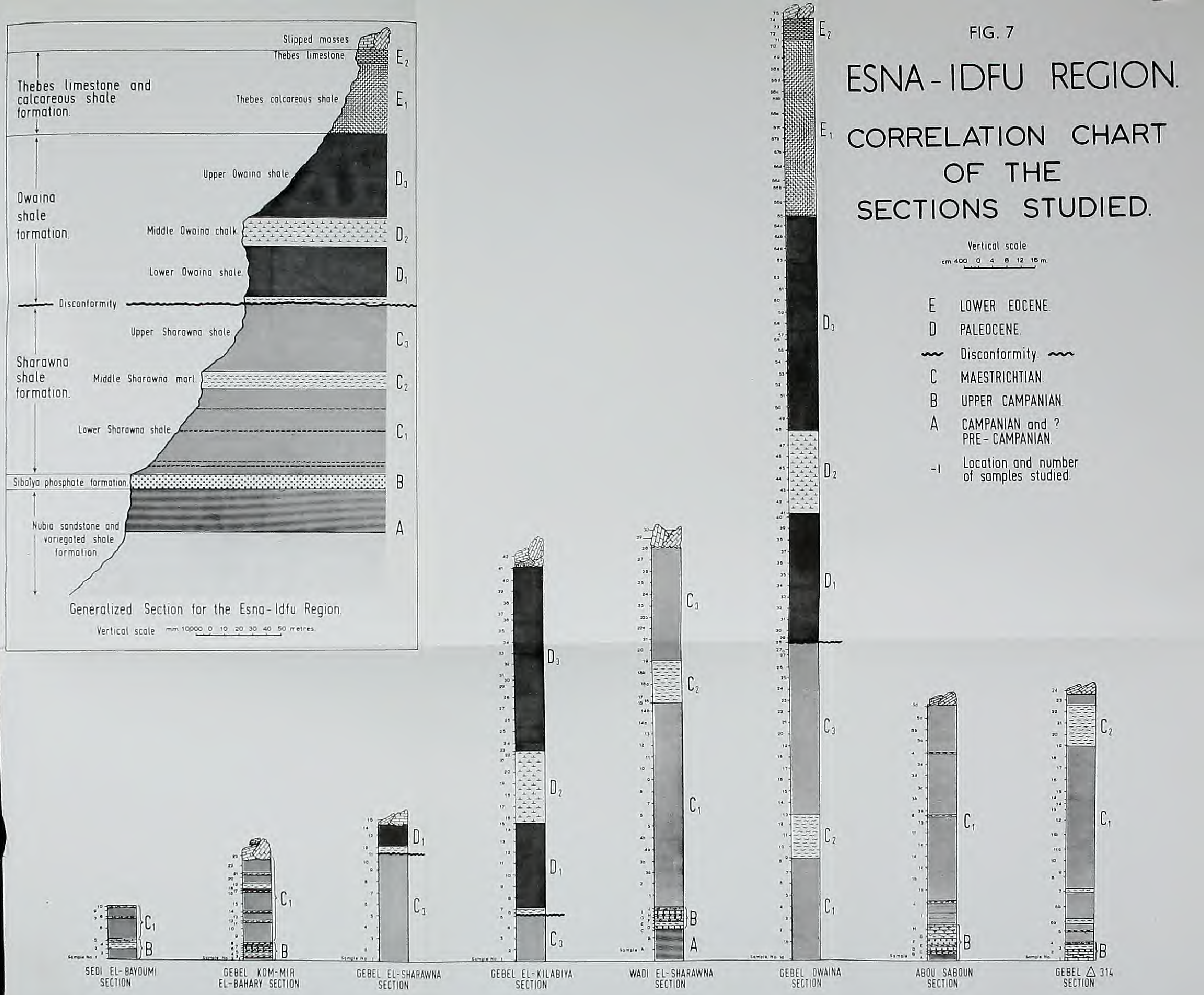
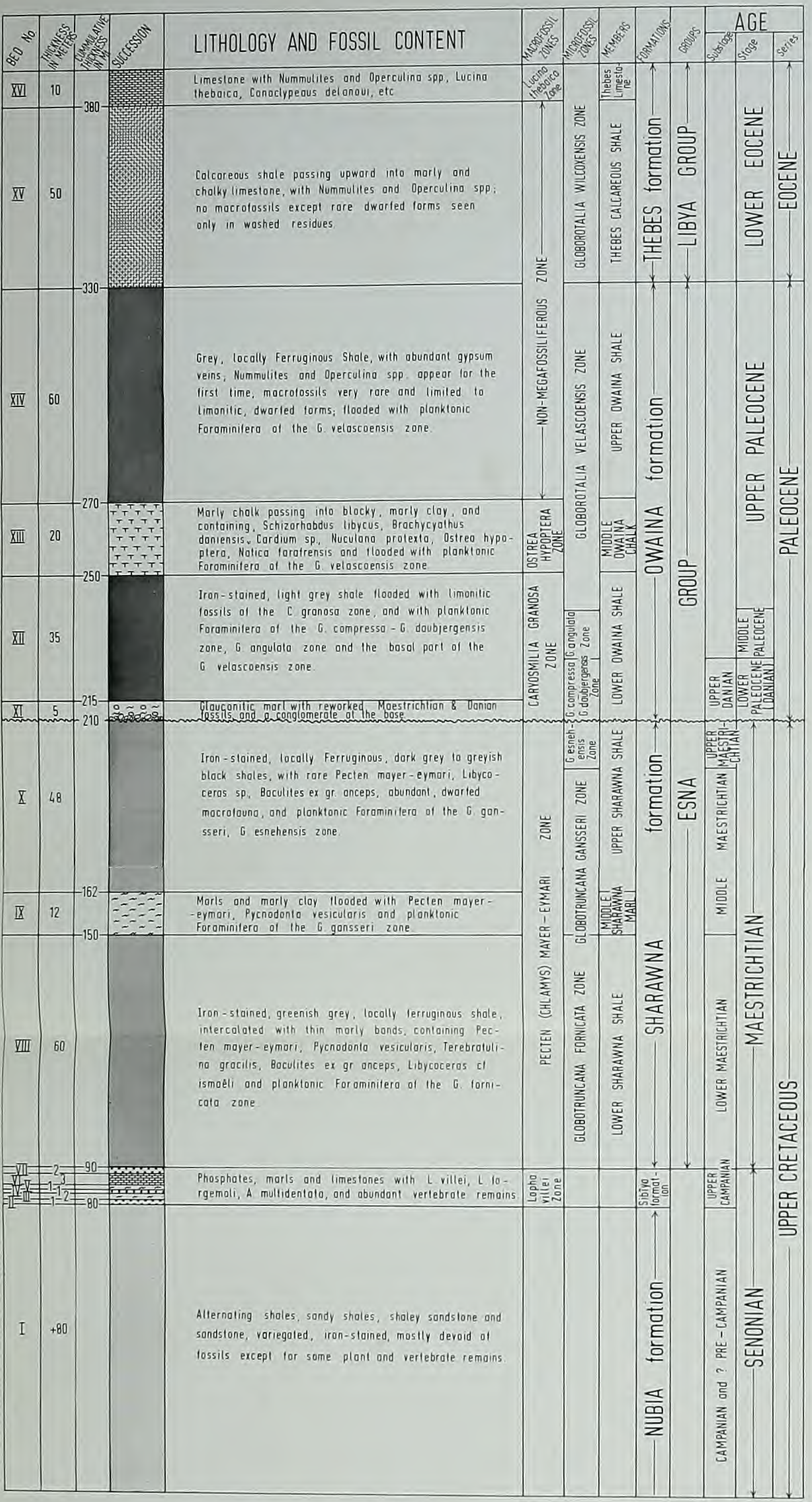


FIG. 7

ESNA - IDFU REGION.

CORRELATION CHART OF THE SECTIONS STUDIED.



Limestone with Nummulites and Operculina spp., Lucina thebaica, Conoclypeaus delanoui, etc.

Calcareous shale passing upward into marly and chalky limestone, with Nummulites and Operculina spp.; no macrofossils except rare dwarfed forms seen only in washed residues.

Grey, locally Ferruginous Shale, with abundant gypsum veins; Nummulites and Operculina spp. appear for the first time; macrofossils very rare and limited to limonitic, dwarfed forms; flooded with planktonic Foraminifera of the G. velascoensis zone.

Marly chalk passing into blocky, marly clay, and containing, Schizorhabdus libycus, Brachycyathus daniensis, Cardium sp., Nuculana protexta, Ostrea hypoptera, Natica farafrensis and flooded with planktonic Foraminifera of the G. velascoensis zone.

Iron-stained, light grey shale flooded with limonitic fossils of the C. granosa zone, and with planktonic Foraminifera of the G. compressa - G. daubjergensis zone, G. angulata zone and the basal part of the G. velascoensis zone.

Glauconitic marl with reworked Maestrichtian & Danian fossils and a conglomerate at the base.

Iron-stained, locally Ferruginous, dark grey to greyish black shales, with rare Pecten mayer-eymari, Libycoceras sp., Baculites ex gr. anceps, abundant, dwarfed macrofauna, and planktonic Foraminifera of the G. gansseri, G. esnehensis zone.

Marls and marly clay flooded with Pecten mayer-eymari, Pycnodonta vesicularis and planktonic Foraminifera of the G. gansseri zone.

Iron-stained, greenish grey, locally ferruginous shale, intercalated with thin marly bands, containing Pecten mayer-eymari, Pycnodonta vesicularis, Terebratulina gracilis, Baculites ex gr. anceps, Libycoceras cf. ismaëli and planktonic Foraminifera of the G. fornicata zone.

Phosphates, marls and limestones with L. villei, L. lorgemoli, A. multidentata, and abundant vertebrate remains.

Alternating shales, sandy shales, shaley sandstone and sandstone, variegated, iron-stained, mostly devoid of fossils except for some plant and vertebrate remains.

FIG. 8. Columnar section of the Upper Cretaceous–Lower Tertiary Rocks of the Esna-Idfu Region.

sion studied. It is characterized by the flood of the various subspecies of the *Globotruncana fornicata* group which is taken as the index species for the zone.

The top part of the *G. fornicata* Zone is marked by the diappearance of *G. fornicata fornicata, G. fornicata manaurensis, G. fornicata globulocamerata, G. contusa scutilla, G. contusa witwickae, G. mariai* and *G. tricarinata tricarinata*, as well as by the first appearance of *G. gansseri gansseri, G. ganserri subganserri, G. ganserri dicarinata, G. lugeoni, G. aegyptiaca duwi, G. conica, G. contusa contusa, G. contusa patelliformis, G. esnehensis, G. rosetta pettersi, G. sharawnaensis, G. stuarti parva, G. subcircumnodifer, G.* sp. *Rugoglobigerina glaessneri, R. macrocephala, R. pennyi, R. pustulata*, and *Trinitella scotti*.

It is also characterized by the presence of *G. adamsi, G. aegyptiaca aegyptiaca, G. arca, G.* cf. *convexa, G. fareedi, G. fundiconulosa, G. gagnebini, G.* cf *gagnebini, G. leupoldi, G. mariei, G. orientalis, G. rosetta rosetta, G. stuarti stuarti, G. stuarti stuartiformis, G. stuarti subspinosa, G. tricarinata columbiana, G. ventricosa, G. havanensis, Rugoglobigerina loetterli, R. rugosa, Hedbergella hessi compressiformis, H. hessi hessi, H. mattsoni, H. monmouthensis*, and *H. petaloidea*.

The *G. fornicata* Zone characterizes the " lower Sharawna shale member " and coincides with the *Terebratulina gracilis* Subzone of the macrofossil classification. Both its planktonic foraminiferal and macrofossil content as well as its stratigraphical position (conformably overlying the Upper Campanian *Lopha villei* Zone) suggest a Lower Maestrichtian age as summarized above (see pp. 46–49).

4. THE *Globotruncana gansseri* ZONE.

This represents the second planktonic foraminiferal zone from the base of the succession upwards. It coincides with both the " Middle Sharawna marl member " and the lower part of the overlying " Upper Sharawna shale member ". It is characterized by the first appearance and the flood of the various subspecies of the *G. gansseri* group, which is taken as the index species for the zone. Its base is marked by the top of the underlying *G. fornicata* Zone, and its top by the diappearance of *G. arca, G. bahijae, G. conica* and *G. sp.* as well as by the great reduction in the number of individuals of the *G. gansseri* group and the flooding of *G. esnehensis*, and by the first appearance of *R. rotundata*.

It is also characterized by the presence of *Globotruncana aegyptiaca aegyptiaca, G. arabica, G. arca, G. bahijae, G.* cf. *convexa, G. fareedi, G. fundiconulosa, G. gagnebini, G. gansseri gandolfii, G. leupoldi, G. mariei, G. orientalis, G. rosetta rosetta, G. stuarti stuarti, G. stuarti stuartiformis, G. stuarti subspinosa, G. youssefi, G. havanensis, Abathomphalus intermedia, Hedbergella hessi compressiformis, H. hessi hessi, H. monmouthensis, H. petaloidea, Rugoglobigerina glaessneri, R. loetterli, R. macrocephala, R. pennyi, R. pustulata, R. rugosa*, and *Trinitella scotti*, as well as by the rare occurrence of the following forms at its base : *G. adamsi, G. fornicata ackermanni, G. fornicata cesarensis, G.* cf. *gagnebini, G. tricarinata colombiana, G. ventricosa* and *Hedbergella mattsoni*.

The *G. gansseri* Zone characterizes the Middle Sharawna marl member as well as the lower part of the Upper Sharawna shale member, and coincides with the *Pecten* (*Chlamys*) *mayereymari* Sub-zone of the macro-fossil classification. Both its planktonic foraminiferal and macrofossil content suggest a Middle Maestrichtian age as indicated above (see pp. 47–49).

5. The *Globotruncana esnehensis* Zone.

This represents the third planktonic foraminiferal zone from the base of the succession upwards, and characterizes the topmost part of the Cretaceous rocks in the Esna–Idfu region. It is distinguished by the flood of *Globotruncana esnehensis* Nakkady & Osman which is taken as the index fossil of the zone. Its upper part is marked by a distinct break and by a well developed conglomerate which separates it from the overlying basal Tertiary. At this break the genera *Globotruncana, Rugoglobigerina, Abathomphalus, Trinitella, Hedbergella, Globigerinelloides, Heterhelix* and *Pseudotextularia*; all ammonites and mosasaurs, as well as a great number of characteristic Upper Cretaceous species belonging to other groups, disappear completely and abruptly.

The lower limit of the *G. esnehensis* Zone is marked by the flood of *Globotruncana esnehensis* and by a great reduction in the number of individuals of the *G. gansseri* Zone which all die out completely in its lower part, except *G. gansseri gandolfii* which continues to the disconformity. The lower limit of this zone is also marked by the disappearance of *G. arca, G. bahijae, G, conica,* and *G.* sp. and by the first appearance of *R. rotundata.*

The *G. esnehensis* Zone is generally characterized by the presence of *Globotruncana aegyptiaca aegyptiaca, G. aegyptiaca duwi, G. arabica, G. contusa contusa, G. contusa patelliformis, G.* cf. *convexa, G. gagnebini, G. mariei, G. stuarti parva, G. subcircumnodifer, G. havanensis, Abathomphalus intermedia, A. mayaroensis, Hedbergella monmouthensis, H. petaloidea, Rugoglobigerina glaessneri, R. loetterli, R. pustulata, R. macrocephala, R. pennyi, R. rotundata* and *R. rugosa,* as well as the rare occurrence of *G. fareedi,* members of the *G. gansseri* group, *G. leupoldi, G. lugeoni, G. orientalis, G. sharawnaensis, G. youssefi,* and *H. hessi hessi* at its base.

The *G. esnehensis* Zone is equivalent in part to the *Abathomphalus mayaroensis* Zone which is considered in various parts of the world to represent the uppermost Cretaceous, and is equated with the established uppermost Maestrichtian *Belemnitella casimirovensis* Zone. However, although *Abathomphalus mayaroensis* was recorded in the *G. esnehensis* Zone, the latter zone could not be named after it, in spite of the advantage of this name in inter-regional correlation, as *A. mayaroensis* was only recorded as a rare form, while *G. esnehensis* was found to flood this part of the succession, wherever examined.

6. The *Globorotalia compressa/Globigerina daubjergensis* Zone.

This represents the fourth planktonic foraminiferal zone from the base of the succession upwards. It characterizes the lower part of the Lower Owaina shale member, which represents the lowermost Tertiary outcrop in the Esna–Idfu region, and the first known definite Danian strata in Egypt. The lower Owaina shale member is separated from the underlying Maestrichtian strata by a marked disconformity and a well developed conglomerate in which a mixture of reworked Maestrichtian macrofossils and typical Danain planktonic Foraminifera are recorded.

The *Globorotalia compressa/Globigerina daubjergensis* Zone is characterized by the complete absence of the typical Upper Cretaceous *Globotruncana, Abathomphalus, Rugoglobigerina, Trinitella, Hedbergella* assemblage, and by the first appearance of the typical Tertiary, *Globigerina*/non-keeled *Globorotalia* assemblage. It is flooded with *Globorotalia compressa* (Plummer) and *Globigerina daubjergensis* Brönnimann which are considered as the index species for the zone.

The base of this zone is marked by the disconformity and by the first appearance of the *Globigerina*/non-keeled *Globorotalia* assemblage. Its top is marked by the disappearance of *Globorotalia compressa, Globorotalia kilabiyaensis, Globigerina daubjergensis* and *Globigerina arabica*, and by the first appearance of *Globorotalia angulata angulata, Globorotalia emilei* and *Globigerina inaequispira*. Moreover, it is characterized by the abundance of the following *Globorotalia* species: *G. pseudobulloides, G. trinidadensis, G. quadrata, G. perclara, G. kilabiyaensis, G. imitata*, and the rare occurrence of *G. ehrenbergi, G. faragi, G. tribulosa* and *G. uncinata uncinata* in its upper part. It is also characterized by the abundance of the following *Globigerina* species: *G. triloculinoides, G. triloculinoides parva, G. belli* and by the rare occurrence of *G. haynesi, G. kozlowskii* and *G. spiralis*, at its top.

The *Globorotalia compressa/Globigerina daubjergensis* Zone corresponds to the lower part of the macrofossil *Caryosmilia granosa* Zone. The planktonic Foraminifera of this zone correlate it with the type Danian and thus prove a Danian age for its rich macrofossil content. However, the reduced thickness of this zone and the flood of *Globorotalia compressa* throughout it, show clearly that the strata it characterizes in the Esna–Idfu region, represent the Upper Danian only, the Lower and Middle Danian being missing (see Troelsen 1957 and Berggren 1960*b*, 1962).

7. THE *Globorotalia angulata* ZONE.

This is the fifth planktonic foraminiferal zone from the base upwards, in the succession studied. It coincides with the upper part of the lower Owaina shale member, and is characterized by the flood of *Globorotalia angulata angulata* (White) and its suspecies *abundocamerata*. Its base is marked by the first appearance of *G. angulata angulata, G. emilei* and by the disappearance of the typical Danian *Globorotalia compressa, G. kilabiyaensis, Globigerina daubjergensis* and *G. arabica*.

The upper limit of this zone is drawn at the first appearance of *Globorotalia velascoensis velascoensis* which characterizes and distinguishes the overlying zone. This limit is also marked by the disappearance of *Globorotalia ehrenbergi* and *G. uncinata carinata*, and by the first appearance of *Globorotalia acuta, G. apanthesma, G.* cf. *convexa, G. occlusa G. pseudomenardii, Globigerina alanwoodi* and *G. velasconesis*.

The zone is characterized by the abundance of the following *Globorotalia* species: *G. angulata angulata, G. angulata abundocamerata, G. ehrenbergi, G. emilei, G. faragi, G. imitata, G. perclara, G. pseudobulloides, G. pusilla pusilla, G. pusilla laevigata, G. pusilla mediterranica, G. quadrata, G. tribulosa, G. uncinata uncinata, G. uncinata carinata* and *G.* sp. It is also distinguished by the abundance of the following *Globigerina* species : *G. haynesi, G. inaequispira, G. kozlowskii, G. spiralis, G. triloculinoides* and *G. triloculinoides parva*.

It is divided into two distinct subzones : a lower, *Globorotalia uncinata* Subzone and an upper, *Globorotalia pusilla* Subzone. The ranges of the various species characteristic of each subzone are shown on Text-figs. 12–16.

The *G. angulata* Zone coincides with the upper part of the *Carysomilia granosa* Zone of the macrofossil classification. Its planktonic Foraminifera as well as its stratigraphical position (conformably overlying typical Upper Danian strata and underlying the *G. velascoensis* Zone of Upper Paleocene age) proves its Middle Paleocene age. However, as discussed earlier, the controversy over the chronological and stratigraphical relationships of the various Paleocene stages and substages, and the disagreement regarding their planktonic foraminiferal content, does not allow one to refer the *G. angulata* Zone to any known Paleocene stage or substage (see pp. 22–29, 59–61).

8. THE *Globorotalia velascoensis* ZONE.

This is the sixth planktonic foraminiferal zone from the base of the succession upwards. It coincides with the upper two members of the Owaina formation, the Middle Owaina chalk and the Upper Owaina shale members, and represents the Upper Paleocene of the sections studied. It is characterized by the flood of *Globorotalia velascoensis velascoensis* (Cushman) and its two subspecies *parva* and *caucasica*, which are here considered as the index species for the zone.

The lower limit of the zone is marked by the first appearance of *G. velascoensis velascoensis*, and its upper limit by the complete disappearance of the last survivors of this species. The lower limit is also defined by the first appearance of the following *Globorotalia* species : *G. acuta, G. apanthesma, G.* cf. *convexa, G. occlusa, G. pseudomenardii*, and the first appearance of both *Globigerina velascoensis* and *alanwoodi*.

Its upper limit, besides being defined by the disappearance of *G. velascoensis velascoensis*, is also marked by the disappearance of the following *Globorotalia* species: *G. acuta, G. angulata angulata, G. apanthesma, G.* cf. *convexa, G. nicoli*, and by the disappearance of the following *Globigerina* species : *G. velascoensis, G. triloculinoides, G. triloculinoides parva, G. inaequispira, G. haynesi, G. chascanona, G. bacuana*, and by the first appearance of *Globorotalia bollii*.

The *G. velascoensis* Zone is generally characterized by the abundance of the following *Globorotalia* species : *G. velascoensis velascoensis, G. velascoensis parva, G. velascoensis caucasica, G. acuta, G. aequa, G. africana, G. angulata angulata,* *G. angulata abundocamerata*, *G. apanthesma*, *G. berggreni*, *G.* cf. *convexa*, *G. emilei*, *G. esnaensis*, *G. faragi*, *G. hispidicidaris*, *G. irrorata*, *G. woodi*, *G. nicoli*, *G. occlusa*, *G. perclara*, *G. pseudomenardii*, *G. pusilla mediterranica*, *G. sibaîyaensis*, *G. tribulosa*, *G. whitei*, as well as the rare occurrence of *G. imitata*, *G. pusilla pusilla*, *G. pusilla laevigata*, *G. quadrata*, *G. pseudobulloides* and *G.* sp. at its base, and *G. wilcoxensis*, *G. loeblichi*, *G. troelseni* at its top.

It is also characterized by the abundance of the following *Globigerina* species : *G. aquiensis*, *G. bacuana*, *G. chascanona*, *G. haynesi*, *G. inaequispira*, *G. mckannai*, *G. nodosa*, *G. soldadoensis*, *G. spiralis*, *G. stonei*, *G. triloculinoides*, *G. triloculinoides parva*, *G. velascoensis* and *G. alanwoodi*.

The *G. velascoensis* Zone is clearly divisible, on the basis of its planktonic Foraminifera, into two distinct subzones : a lower *G. pseudomenardii* Subzone and an upper *G. aequa*/*G. esnaensis* Subzone. The lower subzone is distinguished by its index species, *G. pseudomenardii* Bolli, which does not range into the overlying subzone. The *G. aequa*/*G. esnaensis* Subzone is also characterized by its index species which do not range into the underlying subzone, although rare forms of *G. aequa* may be recorded in the uppermost part of the underlying subzone. The distribution of the various planktonic foraminiferal species in each of these subzones is clearly shown on Text-figs. 12–16.

The *G. velascoensis* Zone corresponds to the *Ostrea hypoptera* Zone and the lower part of the non-megafossiliferous zone in the macrofossil zonal scheme. On the basis of its planktonic foraminiferal content, and stratigraphical position, it is considered to represent the Upper Paleocene as stated above (see pp. 29–31, 49–51).

9. THE *Globorotalia wilcoxensis* ZONE.

This represents the last planktonic foraminiferal zone in the succession studied. It coincides with the Thebes calcareous shale member and probably includes at least part of the overlying Thebes limestone member, although the latter did not yield any identifiable planktonic Foraminifera. It is characterized by the abundance of *Globorotalia wilcoxensis* Cushman & Ponton, which is considered as the index species of this zone.

The lower limit is marked by the disappearance of the following *Globorotalia* species : *G. velascoensis velascoensis*, *G. acuta*, *G. angulata angulata*, *G. apanthesma*, *G.* cf. *convexa* and *G. nicoli* as well as by the disappearance of the following *Globigerina* species : *G. bacuana*, *G. chascanona*, *G. haynesi*, *G. inaequispira*, *G. triloculinoides*, *G. triloculinoides parva*, and *G. velascoensis*. It is also marked by the first appearance of *G. bollii* and the flood of *G. wilcoxensis*. The upper limit of the zone is not really known in the succession studied, as no younger zones have yet been recorded.

The *G. wilcoxensis* Zone is characterized by a flood of *G. wilcoxensis*, which species, though appearing first as rare, scattered individuals in the uppermost part of the underlying zone, is nevertheless considered to be a good index fossil. The zone is also characterized by the abundance of the following *Globorotalia* species : *G. troelseni, G. whitei, G. bollii, G. aequa, G. esnaensis* and *G. loeblichi*, as well as by the abundance of both *Globigerina stonei* and *Globigerina soldadoensis*, and by the rare occurrence at its base of both *Globigerina mckannai* and *Globigerina aquiensis*.

The *G. wilcoxensis* Zone corresponds to the upper part of the non-megafossiliferous zone and possibly the lower part of the overlying *Lucina thebaica* Zone, in the macrofossil classification. On the basis of its planktonic Foraminifera, and stratigraphical position, it is considered to mark the dawn of the Eocene as discussed above (see pp. 31, 32, 51, 52).

10. A ZONE WITH INDETERMINABLE PLANKTONIC FORAMINIFERA :

This zone coincides with the Thebes limestone member, of which only the lowest ten metres crop out in the area studied. This hard, siliceous limestone bed which caps the succession is flooded with *Nummulites, Operculina, Assilina, Discocyclina*, etc., but has not yet yielded any identifiable planktonic Foraminifera, possibly because of its silicification. Several samples of this bed are now being processed for planktonic foraminiferal analysis using different techniques with the hope of recovering some identifiable forms.

These planktonic foraminiferal zones clarify the stratigraphy of the Upper Cretaceous–Lower Tertiary in Egypt, and their recognition in other parts of the world indicates that they can be successfully used for the zonation and world-wide correlation of strata of this age.

V. SYSTEMATIC DESCRIPTIONS

Order FORAMINIFERIDA

Superfamily **GLOBIGERINACEAE** Carpenter, Parker & Jones 1862

Family **GLOBOTRUNCANIDAE** Brotzen 1942

This family is represented in the present study by the four genera, *Globotruncana* Cushman 1927, *Rugoglobigerina* Brönnimann 1952, *Trinitella* Brönnimann 1952, and *Abathomphalus* Bolli, Loeblich & Tappan 1957. Forty-five species and subspecies of *Globotruncana*, seven species of *Rugoglobigerina*, one species of *Trinitella*, and two species of *Abathomphalus* are recorded. Members of the genus *Globotruncana* are discussed in detail, while those of *Rugoglobigerina, Trinitella* and *Abathomphalus* are only listed and will be figured and described in a later publication.

Genus ***ABATHOMPHALUS*** Bolli, Loeblich & Tappan 1957

Type species : *Globotruncana mayaroensis* Bolli 1951

Abathomphalus intermedia (Bolli)

1951 *Globotruncana intermedia* Bolli : 197, pl. 35, figs. 7–9.
1954 *Globotruncana intermedia* Bolli ; Ayala : 399, pl. 7, figs. 2*a–c*.

? 1955 *Globotruncana intermedia intermedia* (Bolli) Gandolfi : 48, pl. 3, figs. 8*a–c*.
? 1956 *Rugotruncana intermedia* (Bolli) ; Brönnimann & Brown : 553, pl. 22, figs. 13–15.
? 1956*b* *Marginotrucana intermedia* (Bolli) Hofker : 333, text-fig. 24.
? 1956*c* *Marginotruncana intermedia* (Bolli) Hofker : 75, pl. 10, figs. 74*a–c*.
? 1960*a* *Globotruncana* (*Marginotruncana*) *intermedia* Bolli ; Hofker : 225, text-fig. 21*a–c*.
1962 *Praeglobotruncana* (*Praeglobotruncana*) *intermedia* (Bolli) Berggren : 31, pl. 7, figs 2*a–c*.

REMARKS. A few specimens of *A. intermedia* (Bolli) were recorded from both the Middle Maestrichtian *G. gansseri* Zone and the overlying Upper Maestrichtian *G. esnehensis* Zone. The species was recorded from the Maestrichtian of Trinidad (Bolli 1951, 1957*a*), of northeastern Colombia (Gandolfi 1955), of Cuba (Brönnimann & Brown 1956), of northwestern Germany and of Holland (Hofker 1956*b*, *c*) and of southern Scandinavia (Hofker 1960*a* ; Berggren 1962).

HYPOTYPE. P.45659.

HORIZON AND LOCALITY. Hypotype from sample No. 16, Wadi EI-Sharawna section.

Abathomphalus mayaroensis (Bolli)

1951 *Globotruncana mayaroensis* Bolli : 198, pl. 35, figs. 10–12.
1953 *Globotruncana mayaroensis* Bolli : Subbotina ; 181, pl. 8, figs. 2*a–c*.
1954 *Globotruncana mayaroensis* Bolli ; Ayala : 407, pl. 10, figs. 1*a–c*.
? 1955 *Globotruncana mayaroensis* Bolli ; Gandolfi : 18, pl. 1, figs. 2*a–c*, text-fig. 4 (10*a–b*).
1956 *Globotruncana mayaroensis* Bolli ; Knipscheer (in Ganss & Knipscheer) : 624, pl. 2, figs. 2*a–c*.
1956 *Rugotruncana mayaroensis* (Bolli) Brönnimann & Brown ; 553–554, pl. 22, figs. 10–12.
1956 *Globotruncana mayaroensis* Bolli ; Wicher : 136, pl. 13, figs. 7, 8.
? 1956 *Globotruncana mayaroensis* Bolli : Said & Kenawy : 151, pl. 5, figs. 23*a–c*.
? 1956 *Globotruncana lapparenti lapparenti* Brotzen ; Said & Kenawy : 150, pl. 5, figs. 14*a–c*.
1957 *Globotruncana* (*Globotruncana*) *planata* Edgell : 115, pl. 4, figs. 7–9.
1957 *Abathomphalus mayaroensis* (Bolli) Bolli, Loeblich & Tappan : 43, pl. 11, figs. 1*a–c*.
1960 *Globotruncana mayaroensis* Bolli ; Vinogradov : 313, pl. 5, figs. 26*a–c*.
1962 *Praeglobotruncana* (*Praeglobotruncana*) *mayaroensis* (Bolli) Berggren : 32–36, pl. 7, figs. 3*a–c*.

REMARKS. Rare specimens of *A. mayaroensis* were recorded from the Upper Maestrichtian (*G. esnehensis* Zone). The species was also recorded from the Upper Maestrichtian of Trinidad (Bolli 1951, 1957*a*), of the Caucasus (Subbotina 1953), of northeastern Colombia (Gandolfi 1955), of Bavaria (Knipscheer 1956), of Cuba (Brönnimann & Brown 1956), of Austria (Wicher 1956), of northern Sinai, Egypt (Said & Kenawy 1956), of Australia (Edgell 1957), of Rumania (Vinogradov 1960) and of southern Scandinavia (Berggren 1962).

HYPOTYPE. P.45660.

HORIZON AND LOCALITY. Hypotype from sample No. 27, Wadi El-Sharawna section.

Genus *GLOBOTRUNCANA* Cushman 1927

Type species: *Pulvinulina area* Cushman 1926

1927*b* *Globotruncana* Cushman : 91 (Type species : *Pulvinulina arca* Cushman 1926).
1941 *Rosalinella* Marie : 237 (Type species : *Rosalina linneiana* d'Orbigny 1839).
1956 *Rugotruncana* Brönnimann & Brosn : 546 (Type species *Rugotruncana tilevi* Brönnimann & Brown 1956).
1956 *Bucherina* Brönnimann & Brown : 557 (Type species : *Bucherina sandidgei* Brönnimann & Brown, 1956).
1956*b* *Marginotruncana* Hofker : 319 (Type species : *Rosalina marginata* Reuss 1845).
1957*a* *Globotruncanella* Reiss : 135 (Type species : *Globotruncana citae* Bolli 1951 = *Globotruncana havanensis* Voorwijk 1937).
1957*a* *Globotruncanita* Reiss : 136 (Type species : *Rosalina stuarti* de Lapparent 1918).
1957*a* *Helvetoglobotruncana* Reiss : 137 (Type species *Globotruncana helvetica* Bolli 1943).

EMENDED DIAGNOSIS: Test free, trochospirally coiled, with wide range of variation in size and shape, highly or moderately spiro-convex, biconvex plano-convex (umbilico-convex), concavo-convex, or even parallel-sided ; dorsal side evolute, highly domed, convex, flat or even concave ; ventral side strongly umbilicate, moderately or strongly protruding, convex, flat or even concave ; equatorial periphery generally rounded or ovoid, sometimes polygonal, either entire or lobate, with single or double keel ; in double keeled forms, the two keels may be parallel or divergent, enclosing a narrow or wide peripheral band either at right angles or inclined to plane or coiling ; axial periphery subrounded, subacute, acute, subtruncate or truncate ; chambers generally arranged in 2–4 whorls, dextrally or sinistrally coiled ; all chambers seen on dorsal side, only those of last whorl seen on ventral side ; initial chambers generally globular, moderately or strongly inflated, later ones variable in shape, being ovoid truncate, lenticular acute, hemispherical, angular conical, angular truncate, angular rhomboid, etc. ; sutures on both sides curved or radial, raised or depressed, sometimes thickened, limbate and beaded ; umbilicus varies in shape and size, rounded, ovoid, stellate or polygonal, moderate or large, with or without an umbilical flange ; primary apertures interiomarginal, umbilical, but umbilicus covered by complex, imperforate cover-plate (tegilla) formed by fusion of apertural flaps extending from each chamber ; these tegilla pierced centrally and at their contacts with umbilical rim by a number of small accessory apertures along which primary apertures and umbilical region in general communicate with outside of test ; tegilla delicate with much thinner wall than rest of test and thus are rarely preserved ; but even when broken they leave remnants along umbilical margin ; wall calcareous perforate, except for imperforate keel or keels, peripheral band and tegilla ; surface smooth or roughened, papillose, nodose, or even spinose ; keel or keels, sutures and umbilical flange either thickened and limbate or strongly beaded ; dorsal keel of each chamber reflected on dorsal side of test as inter-cameral dorsal suture, dorsal keels of successive whorls constituting spiral suture ; ventral keel (when present) reflected on ventral side of test as inter-cameral ventral suture (either raised or depressed) ; it may continue along umbilical rim as raised, beaded, umbilical flange ; i.e. dorsal keel of nepionic stage continuing on following chambers as dorsal inter-cameral sutures, spiral suture and dorsal, marginal keel of last whorl, while ventral keel of nepionic stage (when present) continues as ventral inter-cameral suture, ventral marginal keel of last whorl and sometimes as umbilical flange. In single-keeled forms keel occasionally bifurcating on periphery to form dorsal as well as ventral inter-cameral suture, as in members of *Globotruncana stuarti* group.

DISCUSSION. Cushman (1927*b*) described *Globotruncana* as a new genus, with *Pulvinulina arca* Cushman 1926 as the type species. However, several species of this genus had been previously assigned to the genus *Rosalina* d'Orbigny 1826 (e.g. *R. marginata* Reuss 1845, *R. canaliculata* Reuss 1854 and *R. stuarti* de Lapparent 1918). Thalmann (1933) considered *Rosalina* d'Orbigny to be a junior synonym of *Discorbis* Lamarck 1804, and thus substantiated the validity of the genus *Globotruncana*. However, Brotzen (1948) stated that the type species of *Discorbis* Lamarck has not been determined for certain, and thus retained *Rosalina* d'Orbigny 1826, and included in its synonymy : *Discorbina* Parker & Jones 1862, and *Discorbis* Lamarck of authors (part). Nevertheless, the apertural characters, the large umbilicus, the umbilical cover-plate, the keels and peripheral band, the shape of the chambers, etc., clearly distinguish *Globotruncana* from the above genera.

The brief description of the apertural characters of the genus given by Cushman (1927*b*) led to further complication. He merely stated that the aperture is on the ventral side, and later (1928) added " . . . aperture on the ventral side, often in well-preserved specimens with a thin plate-like structure over the umbilical area . . . " However, Marie (1941) noticed that in morphologically similar forms, the apertures of the previous chambers remain open into the umbilicus. Thus he suggested including these forms in a separate genus which he named *Rosalinella*, with *R. linnei* (d'Orbigny) as type species. He included within his new genus : *Rosalina* d'Orbigny *sensu* de Lapparent 1918, *Globotruncana* Cushman 1927, *Globorotalia* Cushman 1927 (part), as well as *Rosalna* d'Orbigny (part), *Discorbina* Parker & Jones (part), *Globigerina* d'Orbigny (part), *Rotalia* Lamarck (part) and *Truncatulina* d'Orbigny (part) of authors. Marie divided his genus *Rosalinella* on the basis of the peripheral character and general form of test into four subgenera which he did not name, but listed with examples as follows :

I. Test with truncated periphery, bordered by two marginal keels.
    1. Subgenus typified by *Rosalinella linnei* (d'Orbigny).
II. Test with acute periphery (single keeled) :
    (A) Contour regular
        [a] with large umbilicus.
    2. Subgenus typified by *Rosalinella stuarti* (de Lapparent).
        [b] with narrow umbilicus.
    3. Subgenus typified by *Rosalinella velascoensis* (Cushman).
    (B) Contour lobate
    4. Subgenus typified by *Rosalinella appenninica* (Renz).

Thus, he included within his new genus, species typical of *Globotruncana* Cushman 1927, of *Globorotalia* Cushman 1927, and of *Rotalipora* Brotzen 1942. Nevertheless, his description conforms well with that of *Globotruncana* as given by Cushman

(1927, 1928) and emended by later authors. Thus *Rosalinella* Marie 1941 is considered a junior synonym of *Globotruncana* Cushman 1927.

Reichel (1950) divided the genus *Globotruncana* into four subgenera : *Globotruncana s.s.*, *Rotalipora* Brotzen, *Thalmanninella* Sigal and *Ticinella* Reichel. However, the apertural characters of the last three genera are different from those of *Globotruncana* Cushman and they were therefore considered separately by Sigal (1952), Bolli, Loeblich & Tappan (1957) and Banner & Blow (1959).

Gandolfi (1955) added a fifth subgenus to Reichel's classification, considering *Rugoglobigerina* Brönnimann as a subgenus of *Globotruncana* Cushman. However, the absence of true keels and a peripheral band, the constant presence of well-developed surface rugosity, and the fact that the two forms have not yet been proved to grade into one another, favour the consideration of *Rugoglobigerina* as a separate genus.

Brönnimann & Brown (1956) described *Rugotruncana* as a new genus. They distinguished it from *Globotruncana* by the fact that " . . . some or all later chambers exhibit fine discontinuous costellae or traces of costellae.", otherwise their descriptions of the two genera are identical. However, as previously mentioned by Bolli, Loeblich & Tappan (1957), surface ornamentation alone cannot be used as a generic character, and thus *Rogotruncana* should be considered a junior synonym of *Globotruncana*, although Banner & Blow (1959) considered it as a subgenus of the latter. Forms of *Globotruncana* with a highly roughened surface are recorded, and variation of the surface rugosity within the same species population renders generic or subgeneric distinction impossible on this basis alone. Moreover, Brönnimann & Brown (1956) included *Abathomphalus intermedia* (Bolli) and *A. mayaroensis* (Bolli) within *Rugotruncana*, in spite of the difference in the apertural characters of the two genera. They also described *Bucherina* as a monotypic genus. They stated that it resembles *Globotruncana* and *Rugotruncana*, but differs from both " in lacking an umbilical cover-plate and in exhibiting a shift in the axis of coiling ". They further stated that " short apertural flaps extend into the umbilicus but do not form a cover-plate". However, as mentioned above, the cover-plate is a very delicate structure which is rarely well-preserved, and the shift in the axis of coiling is not a generic character. The establishment of a new genus on such a weak basis cannot be accepted, and *Bucherina* Brönnimann & Brown is therefore considered a junior synonym of *Globotruncana* Cushman. Again, these authors stated that *Globigerina mckannai* White may possibly belong to their new genus *Bucherina*. However, no apertural flaps were ever observed in *G. mckannai*, which is a true *Globigerina*, recorded only from the Upper Paleocene and Lower Eocene, where no globotruncanid-like forms are known.

Hofker (1956) proposed *Marginotruncana* as a new genus. He distinguished it from *Globotruncana* Cushman on the basis of a so-called strongly reduced primary aperture (protoforamen) in the latter, which is either completely lost or fused with a secondary aperture (deuteroforamen) in the former. He included within *Marginotruncana*, forms which actually belong to *Globotruncana* Cushman, *Abathomphalus*

Bolli, Loeblich & Tappan, *Praeglobotruncana* Bermudez and *Rotalipora* Brotzen, all of which differ markedly in their apertural characters. Moreover, a deuteroforamen, such as described by Hofker, had not been recorded in any of the forms he included in his *Marginotruncana* [e.g. *G. marginata* Reuss, *G. stuarti* (de Lapparent), *G. contusa*, (Cushman), etc.] which conform precisely with the description of the genus *Globotruncana* as given by Cushman (1927) and emended by later authors. Thus *Marginotruncana* Hofker is considered a junior synonym of *Globotruncana* Cushman.

Reiss (1957) described *Globotruncanita* as a new genus and distinguished it from *Globotruncana* Cushman by its chamber form which is mostly polygonal in outline, its entirely single keel, and by its " distinctive apertural characters ". However, as admitted by Reiss, polygonal chambers are also recorded in *Globotruncana* Cushman. Again, the character of the keel, whether single or double, is of specific importance only within the genus *Globotruncana*, and cannot be used as a basis for splitting it into two distinct genera. Forms with a double keel are clearly shown in the present study to evolve into single-keeled forms (e.g. *G. arca* → *G. leupoldi*), all transitional stages being present. Finally, there is no fundamental difference in the apertural characters of the two genera as described by Reiss (1957); both have interiomarginal, umbilical primary apertures, and a cover-plate with accessory apertures. Thus *Globotruncanita* Reiss is considered a junior synonym of *Globotruncana* Cushman.

Reiss also described *Globotruncanella* and *Helvetoglobotruncana* as two new genera and stated that *Globotruncanella* is closely related to *Praeglobotruncana*, although from his description, it is clearly seen that its apertural characters relate it to *Globotruncana* not to *Praeglobotruncana*. However, he distinguished *Globotruncanella* by its flatly trochospiral test and its undifferentiated keel which never shows any tendency to split into two keels (although his type species was observed in the present study and by Brönnimann & Brown (1956) to have an occasional ventral keel in the last chamber or two). Otherwise, his description conforms well with that of *Globotruncana* Cushman. As the degree of flattening of the test and the double- or single-keeled nature of the peripheral band are characters of specific, rather than generic, importance, *Globotruncanella* Reiss is considered a junior synonym of *Globotruncana* Cushman.

Similarly *Helvetoglobotruncana* was only distinguished by its rounded chambers and its subperipheral, monochotamic keel. Again, chamber shape and position of the keel cannot be accepted as generic characters. Forms of *Globotruncana* with globular chambers and a dorsally-shifted keel (e.g. *Globotruncana arabica* sp. nov.) are recorded in the present paper, and make the establishment of a new genus impossible on the basis of such minor morphological characters. Thus *Helvetoglobotruncana* Reiss is also considered a junior synonym of *Globotruncana* Cushman.

Globotruncana Cushman 1927 is distinguished from *Rugoglobigerina* Brönnimann 1952 by its keel or keels, imperforate peripheral band, less globular chambers and less rugose surface. *Trinitella* Brönnimann 1952 is transitional in character between *Globotruncana* and *Rugoglobigerina*. It can neither be included in the former because it lacks an entire keel and an imperforate peripheral band, nor in the latter because of its compressed last chambers and partially developed keel. Thus it is considered here separately, in spite of the fact that it is represented by only one species, until further study can reveal its true position.

Globotruncana is distinguished from *Abathomphalus* Bolli, Loeblich & Tappan 1957 by its interiomarginal, umbilical aperture, which is extraumbilical in *Abathomphalus* ; by its generally large umbilicus, which is very much reduced in the latter genus ; by its complex tegilla which is single in *Abathomphalus* and by the fact that its accessory apertures are both infra- and intralaminal, not only infralaminal as in *Abathomphalus*.

Globotruncana differs from *Praeglobotruncana* Bermudez 1952 in its umbilical aperture, umbilical cover-plate, and accessory apertures. It differs from both *Globorotalia* Cushman 1927 and Hedbergella Brönnimann & Brown 1958 in the above mentioned characters, as well as in the constant presence of a single or double keel.

REMARKS. The confusion surrounding most *Globotruncana* species has led the author to split the present forms as much as their morphology and stratigraphical ranges would allow. No splitting on the basis of minor morphological characters or of rare specimens has been attempted. This has helped to clarify the nature of each of the described forms, although further study (serial thin-sectioning and statistical analysis) may favour the merging of some of these morphologically similar forms.

The present study has shown that the characters of specific value within the genus *Globotruncana* are as follows :

1. The shape of the test (biconvex, planoconvex, concavoconvex, sprioconvex or parallel-sided), which is a function of the relative shapes of both the dorsal and the ventral sides. Variation within the range of each shape has been observed, and is not of any taxonomic importance.
2. The character of the keel, whether single or double, or transitional from one to the other ; and in the double-keeled forms the position of the two keels relative to each other and to the rest of the test (parallel or divergent, closely- or widely-spaced, equally- or unequally-developed, marginally situated or shifted either to the dorsal or the ventral side), which affect the size, shape and position of the peripheral band.
3. The shape of the chambers on both the dorsal and ventral sides, the number of chambers in the test and in the last whorl, as well as the arrangement of the chambers. This affects the general shape of the test, the shape of its equatorial periphery (rounded, subrounded, polygonal, entire or lobate) ; the character of the sutures on both sides of test (straight or curved, raised or depressed), and the shape of the umbilicus. However, it should be noted that, other things being equal, variation in any of these characters separately is not of any taxonomic value.
4. Character of the surface, whether smooth or rough, but not degree of rugosity.

Evolutionary Development of *GLOBOTRUNCANA*

Although the evolutionary development of the genus *Globotruncana* has been discussed by several authors e.g. Reichel (1950), Hagn & Zeil (1954), Gandolfi (1955), Brönnimann & Brown (1956) and Cita (1963), its origin remains uncertain. However, the fact that the early part of the test in all representatives of the genus is reminiscent of *Globigerina*, led to the belief that the genus had probably evolved from a generalized "*Globigerina*-like" stock. On the other hand, *Globigerina*, as fixed by the original designation of its type species (*Globigerina bulloides* d'Orbigny 1826) is known to have appeared first at the base of the Danian (i.e. after the disappearance of the genus *Globotruncana*), a fact previously recognized by various authors and confirmed by the present study. This throws doubt on the validity of the previous records of *Globigerina* species in Cretaceous and Upper Jurassic rocks. A restudy of these forms may prove them to be species of *Hedbergella*, *Rugoglobigerina*, *Praeglobotruncana*, *Globotruncana*, or other genera. Nevertheless, with the limits of our present knowledge, the genus *Globotruncana* may have originated in one of the following ways :

1. *Praeglobotruncana* evolved into *Globotruncana* by the confinement of the aperture to an interiomarginal, umbilical position, and by the development of the umbilical cover-plate ; and *Globotruncana* in its turn evolved into *Rugoglobigerina* by the loss of the keel or keels and by the development of distinct surface rugosity.
2. *Hedbergella* evolved in one direction into *Praeglobotruncana* which continued its evolution as mentioned above, and in another direction, into *Globotruncana* by the confinement of the aperture to an interiomarginal, umbilical position, and by the development of both the cover-plate and the keel (or keels) : *Globotruncana*, in its turn evolved into *Rugoglobigerina* by the loss of the keel or keels and by the development of surface rugosity as mentioned above.
3. Some of the so-called "*Globigerina*" species in the lower part of the Upper Cretaceous and even in the Lower Cretaceous may possibly belong to *Rugoglobigerina* (although the genus has, up till now, been recorded from the Campanian and Maestrichtian only), but the cover-plate is either broken or has been lost during the process of fossilization ; hence it can be suggested that a hypothetical "*Rugoglobigerina*" stock has probably evolved into *Globotruncana* by the flattening of the dorsal side and the development of keel or keels, although Gandolfi (1955) strongly emphasized the fact that most *Globotruncana* species had undergone a process of "globigerinization" to develop into *Rugoglobogerina*.

However, nothing can be decided about the origin of *Globotruncana* until the earliest known globigerinid forms have been carefully examined and traced to the first known *Globotruncana* species, either directly or indirectly through *Hedbergella*, *Praeglobotruncana*, or *Rugoglobigerina*.

Several evolutionary trends demonstrated by one or more lineages of the genus *Globotruncana*, were suggested by various authors, (e.g. Gandolfi 1955 ; Brönnimann

& Brown 1956 and Cita 1963). However, the fact that the present study is mainly concerned with the Maestrichtian *Globotruncana*, makes it difficult to go into detail, although the phylogenetic development of each of the species discussed here, is dealt with in the remarks on each species, and the various lineages suggested in the present study are summarized in Text-fig. 10. The extension of such lineages downwards in older strata can only be substantiated by the study of continuous sections throughout the Upper Cretaceous. Nevertheless, the main evolutionary tendencies observed in the various *Globotruncana* species discussed in the present work can be briefly summarized as follows :

(a) A tendency to reduce the ventral keel.
(b) A tendency to reduce the size of test.
(c) A tendency to increase the surface rugosity.

Again, comparison with the known *Globotruncana* species in the Turonian, Coniacian, Santonian and Campanian, shows that :

1. The tendencies towards reduction of the ventral keel in double-keeled *Globotruncana*, and towards increase in surface rugosity exist throughout the Upper Cretaceous.
2. A tendency towards the gradual increase in the size of test is clearly documented ; it reaches its maximum in the Lower Maestrichtian and is then reversed towards the Upper Maestrichtian.
3. A tendency to increase the height of coiling in spiroconvex forms is observed from the Turonian throughout the Maestrichtian, and manifests itself in the flooding of Maestrichtian strata with representatives of the *G. contusa* group, *G. conica*, *G. esnehensis*, *G. sharawnaensis*, *G. orientalis* and *G. fareedi*.
4. A tendency, upwards in the section, towards the modification of the shape of the chambers in the last one or two whorls from globular to ovoid, lenticular, petaloid, crescentic, trapezoidal, rectangular or even polygonal, although some of the last representatives still maintain the globular shape of the chambers. This modification of the chamber shape in the last one or two whorls affects the general shape of the test and also the shape and size of the umbilicus.
5. There is a general increase in the number of individuals of each species and in the number of species and subspecies between the Turonian and the Maestrichtian. This is accelerated in the uppermost Cretaceous, and results in the younger species having a much shorter range than the older ones.

These tendencies, in general, agree well with previous observations by other authors, especially Brönnimann & Brown (1956), who also noted tendencies towards the "refinement of shell material" and towards an increase in the size of the apertural flaps at stratigraphically higher levels. Although exceptions have been noted to the above-mentioned trends, their existence is in no way invalidated.

Globotruncana adamsi sp. nov.

(Pl. 8, figs. 2*a*–*d*.)

Diagnosis. A *Globotruncana* distinguished by its small to medium-sized, dome-shaped, distinctly spiroconvex test ; its highly convex dorsal side and almost flat ventral one ; globigerine, strongly inflated early chambers and crescentic, distinctly elongated, gently plicate ones in the last whorl ; ovoid, slightly to moderately overlapping chambers on ventral side ; two well-developed marginal keels, wide inclined peripheral band, and generally smooth to delicately papillose surface.

Description. Test large, spiroconvex, roughly ovoid in outline ; dorsal side highly convex and moderately inflated ; ventral side almost flat ; equatorial periphery ovoid, slightly lobate, with two well-developed, heavily beaded marginal keels ; axial periphery truncate, bluntly subangular ; chambers on the dorsal side not all clear, but apparently 23 in number, arranged in 4 dextrally coiled whorls ; the initial chambers are small, globular, weakly inflated and increase very slowly in size ; they are followed by slightly larger, strongly inflated, globular chambers which increase moderately in size ; the last whorl is composed of 5 large chambers which increase rapidly in size, and are subglobular and strongly inflated in the early part, becoming crescentic, strongly elongated in the direction of coiling later ; the last chamber is weakly plicated ; on the ventral side there are 5 chambers which increase moderately in size, being subglobular in the early part, ovoid, slightly inflated and strongly overlapping later ; sutures on the dorsal side slightly curved, depressed in the early part, strongly curved, raised and distinctly beaded later ; on the ventral side the sutures are straight, radial, strongly depressed at first, curved forward, delicately beaded, slightly raised or running in sutural depressions later ; umbilicus roughly pentagonal in outline, wide, deep, bordered by slightly raised, delicately beaded umbilical ridges, and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla, with accessory apertures, only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface delicately papillose especially on the ventral side ; the two marginal keels are well-developed and heavily beaded, the ventral one is slightly shifted towards the ventral side, and thus they enclose a relatively wide, slightly inclined peripheral band which becomes progressively narrower towards the last chamber.

Dimensions of holotype.

Maximum diameter	=	0·46 mm.
Minimum diameter	=	0·36 mm.
Thickness	=	0·25 mm. (Across middle part of test)

Main variation.

1. Chambers 13–24, arranged in 3–4 whorls, generally dextrally coiled.
2. Chambers in the last whorl 4–6.
3. The two keels are either equally developed or the ventral one slightly weakens towards the last chamber.

REMARKS. *G. adamsi* sp. nov. is morphologically similar to both *G. fornicata fornicata* Plummer and *G. convexa* Sandidge. It is distinguished from the former by its dome-shaped, distinctly spiroconvex test, and from the latter by its less truncate axial periphery, better developed marginal keels, and strongly elongated chambers in the last whorl which overlap more on the ventral side.

Globotruncana adamsi sp. nov. is believed to have evolved from *G. fornicata fornicata* Plummer into *G. contusa patelliformis* Gandolfi, as suggested by the morphological features and stratigraphical ranges of these three forms. It was probably confused in the past with *G. fornicata* Plummer (e.g. Cita 1948) and with *G. caliciformis* (de Lapparent) (e.g. Cita 1948, Bolli 1951 and Gandolfi 1955). However, these forms are not included in the synonymy of the present species as they lack the distinctly elongated chambers in the last whorl and were incompletely described by their respective authors.

This species is named after Dr C. G. Adams of the British Museum (Natural History), London.

HOLOTYPE. P.45511.

PARATYPES. P.45510.

HORIZON AND LOCALITY. Holo- and paratypes from sample No. 4, Abou Saboun section.

STRATIGRAPHICAL RANGE. The species is common to abundant throughout the Lower Maestrichtian *G. fornicata* Zone and the basal part of the Middle Maestrichtian *G. gansseri* Zone. It fades out gradually upwards in the section, and dies out completely in the lower part of the latter zone.

The forms described by Cita (1948) as *G. fornicata* Plummer and *G. caliciformis* (de Lapparent) which may possibly belong to the present species, were recorded from the Santonian–Maestrichtian and the Upper Campanian–Maestrichtian of Italy respectively. Similar forms described as *G. caliciformis* (de Lapparent) by Bolli (1951) and as *G. caliciformis caliciformis* (de Lapparent) by Gandolfi (1955) were recorded from the Maestrichtian of Trinidad and from what was described as Upper Santonian–Campanian of northeastern Colombia respectively.

Globotruncana aegyptiaca aegyptiaca Nakkady

(Pl. 3, figs. 4*a–d* ; Pl. 4, fig. 1)

1950 *Globotruncana aegyptiaca* Nakkady : 690, pl. 90, figs. 20–22.
? 1954 *Globotruncana aegyptiaca* Nakkady ; Nakkady & Osman : 75–76, pl. 20, figs. 20*a–c*.
1956 *Rugotruncana skewesae* Brönnimann & Brown : 550–551, pl. 23, figs. 4–6.

EMENDED DIAGNOSIS. A *Globotruncana* distinguished by its medium to large-sized, distinctly quadrilobate test ; flat to weakly arched dorsal side and strongly protruding ventral one ; highly lobate equatorial periphery ; two strongly developed marginal keels ; curved, raised, beaded dorsal sutures and radial incised ventral ones ; thick limbate umbilical flange ; very wide umbilicus, and generally rough surface.

Description. Test large, quadrilobate in outline, planoconvex, umbilicoconvex, coiled in a very low trochospire ; dorsal side almost flat although the early chambers are very weakly raised above the circumambient last whorl ; ventral side strongly inflated and distinctly protruding ; equatorial periphery roughly quadrate, very distinctly lobate, with two well-developed, much thickened, beaded keels ; axial periphery truncate ; chambers on the dorsal side 17, arranged in 3 dextrally coiled whorls ; the initial ones are small, inflated, globigerine, increase slowly in size and are followed by typically crescentic chambers which increase moderately in size as added ; the last whorl is composed of 4, large, petaloid chambers which increase so slowly that they all appear to be equal in size ; on the ventral side the chambers are 4, large, roughly ovoid, distinctly protruding and increase very slowly in size ; sutures on the dorsal side are curved, raised, thickened and beaded ; on the ventral side they are short, radial and depressed ; umbilicus quadrate in outline, very wide, deep, surrounded by much thickened, limbate, delicately beaded ridges, and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface distinctly papillose in the early part, smooth in the later part with the papillae extremely well developed on the early chambers of the last whorl especially on the ventral side ; the two marginal keels are almost parallel to each other and enclose a wide, depressed peripheral band.

Dimensions of described specimen.

Maximum diameter = 0·48 mm.
Minimum diameter = 0.43 mm.
Thickness = 0·23 mm.

Main Variation.

1. Chambers 15–19, arranged in 2½–3 whorls ; generally dextrally coiled but sinistral forms also occurr (out of 500 specimens picked at random, 4 coiled sinistrally).
2. Chambers in the last whorl 4–4½, very rarely 5, increasing very slowly in size.
3. Chambers on the dorsal side flat, very weakly inflated, sometimes even depressed ; on the ventral side the chambers are always strongly inflated.
4. Marginal keels, sutures and umbilical flange either heavily papillose or just thickened and limbate.
5. The two keels are either equally developed or the ventral keel is sometimes reduced on the last chamber.
6. Surface delicately papillose in early part, smooth in later part ; sometimes the papillae are so strongly developed that they give the surface a roughly nodose, or even spinose appearance. The beads on the marginal keel also taper out sometimes in the form of spine-like projections.

REMARKS. *Globotruncana aegyptiaca* was first validly described by Nakkady (1950). He had, however, previously (1949) used the name without any description or figures.

Nakkady (1950) gave only the dorsal view of the holotype, and the ventral and lateral views of two different paratypes. His choice of the paratype (1950, pl. 90, fig. 22) was rather unfortunate as it is a deformed specimen which does not reflect the ventral character of the holotype or the other paratypes. He described the umbilicus as wide, while on his fig. 22 it was shown to be rather narrow. He also stated that the dorsal side is always flat and that the periphery is " single keeled in most specimens but occasionally with a double keel ". However, examination of the holotype and paratypes of Nakkady (B.M.N.H.) Nos. P.41773 and P.41774, respectively) showed clearly that all the specimens are double keeled with a rare tendency towards the reduction of the ventral keel on the last chamber only (e.g. the holotype), and that the dorsal side is not always perfectly flat, but is sometimes weakly inflated, giving the test a very gently arched appearance.

Nakkady (1950) described as varieties of *G. aegyptiaca* two distinct forms which he named *G. aegyptiaca* var. *duwi* and *G. aegyptiaca* var. *I*. Examination of the holotype of *G. aegyptiaca* var. *duwi* Nakkady (B.M.N.H. No. P.41775) and 3 paratypes, (P.41776), and comparison with specimens in the present study, showed clearly that this variety is worthy of distinction as a separate subspecies, in contrast to Berggren's (1962) statement that it can probably be included in *G. aegyptiaca*. Thus the name is changed here to *G. aegyptiaca aegyptiaca* to distinguish it from *G. aegyptiaca duwi*.

Globotruncana aegyptiaca var. *I*. Nakkady is a single keeled form which most probably belongs to the *G. gansseri* Bolli group, as previously mentioned by Berggren (1962) and substantiated by the examination of Nakkady's holotype and one paratype (B.M.N.H. Nos. P.41777 and P.41778 respectively).

Berggren (1962) considered *G. gagnebini* Tilev to be a junior synonym of *G. aegyptiaca* Nakkady. However, the study of a great number of individuals of both species has revealed that they are morphologically distinct. *Globotruncana gagnebini* has a less lobulate, more tightly coiled, distinctly elongate test ; chambers which increase very rapidly in size, a much larger or much smaller last chamber and a greater number of chambers in the last whorl.

Nakkady & Osman (1954) recorded *G. aegyptiaca aegyptiaca* from the Esna shales and chalk of both the Qabeliat and Sudr sections (southwestern Siani, Egypt), but their figures are not at all clear.

Brönnimann & Brown (1956) described as *Rugotruncana skewesae* from the Middle Maestrichtian of Texas, a form which only differs from the holotype of *G. aegyptiaca aegyptiaca* Nakkady in having a distinctly developed spinose periphery, and faint, discontinuous costellae on the early chambers of the last whorl on the ventral side. Forms of *G. aegyptiaca aegyptiaca* with a distinctly spinose periphery and spinose early chambers on the ventral side were mentioned by Nakkady (1950), were observed in his paratypes (B.M.N.H. No. P.41774), and are recorded in the present study. Brönnimann & Brown 1956 stated that " The distinctive feature of *Rugotruncana skewesae* n. sp. is its very flat dorsal side. *Globotruncana concavata* (Brotzen) is the only globotruncanid known to us to have flatter dorsal side." Apart from the fact that *G. concavata* has a concave rather than a flat dorsal side, and that there are at least twenty known *Globotruncana* species and subspecies with a flat dorsal side, it is clear from their statement that these authors had completely overlooked *G. aegyptiaca* and its related forms which were described at least six years before their *R. skewesae*. Moreover, they described the last whorl in *R. skewesae* as having 5 or 6 chambers, and included in its synonymy forms such as *G. rosetta* (Carsey) of Plummer (1927) and *G. arca* (Cushman) of Jennings (1936) which are actually *G. gagnebibi* Tilev, thus indicating that they had also included within *R. skewesae* forms related to *G. gagnebini*. However, as the holotype of *R. skewesae* is identical with *G. aegyptiaca aegyptiaca* it is considered to be a junior synonym of the latter.

Said & Kenawy (1956) described as *G. aegyptiaca* Nakkady, an entirely single-keeled form which is apparently *G. stuarti parva* Gandolfi, as mentioned under the latter species.

The evolutionary history of *G. aegyptiaca aegyptiaca* is not clearly understood, although the morphological features of the species may suggest its evolution from *G. ventricosa* White through *G. gagnebini* Tilev and into *G. aegyptiaca duwi* Nakkady. However, it is not known whether *G. gagnebini* appears lower in the section than *G. aegyptiaca aegyptiaca* or not, as the two species were always confused with one another. In the sections studied, both species were found to occur together from the basal part of the Maestrichtian to the disconformity separating it from the overlying basal Tertiary. Thus it is not excluded that the two species might have evolved from two distinct but morphologically similar, forms. If so, the ancestral stock of *G. aegyptiaca aegyptiaca* may be sought in a form other than *G. ventricosa* White, which is more closely related to *G. gagnebini* Tilev. *Globotruncana tricarinata colombiana* Gandolfi is the only known, morphologically similar *Globotruncana* species which appears in older strata, and thus may possibly represent the ancestral stock from which *G. aegyptiaca aegyptiaca* has evolved.

HYPOTYPES. P.45512–13.

HORIZON AND LOCALITY. Figured specimens from Sample No. 16, Gebel Owaina section.

STRATIGRAPHICAL RANGE : Nakkady (1950) described *G. aegyptiaca aegyptiaca* from the Maestrichtian Esna shale of the Abu Durba section, western Sinai, Egypt, and recorded it as rare to abundant in the chalk of W. Mellaha (Eastern Desert), the shale of W. Danili (western Sinai), and frequent to abundant in the chalk of G. Duwi (Eastern Desert), Egypt. The species was also recorded from the Campanian–Maestrichtian of both the Qabeliat and Sudr sections, Sinai, Egypt (Nakkady & Osman 1954), and as *R. skewesae* from the Middle Maestrichtian of the Navarro group of Texas, (Brönnimann & Brown 1956).

In the Esna–Idfu region, *G. aegyptiaca aegyptiaca* floods the whole of the Maestrichtian section, being extremely abundant in the *G. fornicata* and *G. gansseri* Zones, fading out gradually in the top part of the overlying *G. esnehensis* Zone, and dying out completely just below the disconformity separating the Maestrichtian from the overlying Paleocene.

Globotruncana aegyptiaca duwi Nakkady

(Pl. 3, figs. 5*a–c*)

1950 *Globotruncana aegyptiaca* Nakkady var. *duwi* Nakkady : 690, pl. 90, figs. 17–19.
1954 *Globotruncana aegyptiaca* var. *duwi* Nakkady : Nakkady & Osman : 76, pl. 20, figs. 21*a–c*.

Emended diagnosis : A *Globotruncana aegyptiaca* with much smaller test and fewer chambers increasing very rapidly in size in last whorl ; ovoid to subtriangular, slightly lobate periphery, and rougher surface.

Description. Test medium-sized, roughly ovoid in outline, planoconvex, umbilicoconvex, coiled in a very low trochospire ; dorsal side almost flat, ventral side distinctly protruding ; equatorial periphery roughly ovoid, moderately lobate, with two well-developed, beaded keels ; axial periphery truncate ; chambers on the dorsal side, 11, arranged in 2 dextrally coiled whorls ; the initial chambers are small, globigerine, inflated, almost masked by the surface rugosity and increase slowly in size ; the last whorl is composed of 4 chambers which increase so rapidly in size that the last one constitutes about half of the test ; on the ventral side the chambers are 4, large, strongly inflated, distinctly protruding and increase very rapidly in size ; sutures on the dorsal side are curved, raised and beaded ; on the ventral side they are slightly curved forward, depressed and beaded ; umbilicus roughly quadrate in outline, relatively wide, deep, bordered by thick, raised, beaded ridges and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface rough, distinctly papillose and spinose in the early part, with the roughness decreasing gradually towards the last chamber ; the two marginal keels are almost parallel to each other and enclose a wide, depressed, slightly inclined peripheral band.

Dimensions of described specimen.

Maximum diameter = 0·40 mm.
Minimum diameter = 0·30 mm.
Thickness = 0·22 mm.

Remarks. *Globotruncana aegyptiaca duwi* was first described by Nakkady (1950) as a variety of *G. aegyptiaca*. However, the present study has shown that it is morphologically distinct from *G. aegyptiaca aegyptiaca* and that it appears in stratigraphically younger strata. Thus it is here raised to subspecific rank, although Berggren (1962) stated that it can probably be included in *G. aegyptiaca s.s.* *Globo-*

truncana aegyptiaca duwi is believed to have evolved from *G. aegyptiaca aegyptiaca* as suggested by their morphological features and stratigraphical distribution.

Gandolfi (1955 : 21, 22 ; text-fig. 5, 2*a–c*) included in his G. *tricarinata colombiana*, a form which possibly belongs to *G. aegyptiaca duwi*.

HYPOTYPE. P.45514.

HORIZON AND LOCALITY. Figured specimen from sample No. 16, Gebel Owaina section.

STRATIGRAPHICAL RANGE. Nakkady (1950) described *G. aegyptiaca duwi* from the Upper Cretaceous chalk of Gebel. Duwi section, Kossier area, Eastern Desert, Egypt, where it was described as rather frequent. It was also recorded from the Campanian–Maestrichtian of southern and western Sinai, Egypt (Nakkady & Osman 1954) and from the Maestrichtian of Um El-Huetat section, Eastern Desert, Egypt (Ansary & Fakhr 1958).

In the Esna–Idfu region, *G. aegyptiaca duwi* appears in the basal part of the *G. gansseri* Zone, and increases gradually in number upwards in the section becoming abundant in the upper part of this zone, and then fades out gradually, dying out completely at the top of the overlying *G. esnehensis* Zone.

Globotruncana arabica sp. nov.

(Pl. 6, figs. 3*a–d* ; Pl. 11, fig. 4)

DIAGNOSIS. A *Globotruncana* with large, concavo-convex, strongly umbilico-convex test ; entirely single keel strongly shifted towards dorsal side ; chambers increasing slowly in size and distinctly inflated on ventral side ; very rough surface and large umbilicus.

DESCRIPTION. Test large, subcircular, globular in outline, concavo-convex, distinctly umbilico-convex, coiled in a very low trochospire ; dorsal side shallowly concave, flat in the early part, slightly tilted inward in the last whorl ; ventral side strongly inflated and distinctly protruding ; equatorial periphery subcircular, globular and distinctly lobate, with a single, well developed, beaded keel which is strongly shifted towards the dorsal side ; axial periphery subrounded, very gently truncate ; chambers on the dorsal side about 17, arranged in 3 dextrally coiled whorls ; the initial chambers are small, globular, weakly inflated, almost masked by the surface rugosity and are followed by slightly larger, subglobular, weakly inflated ones ; the last whorl is composed of 5 large, subglobular, compressed chambers which increase slowly in size, are slightly elongated in the direction of coiling and strongly tilted inward towards the initial part ; on the ventral side the chambers are 5, large, subglobular, strongly inflated, distinctly protruding, and enlarging so slowly that they all appear roughly equal in size ; sutures on the dorsal side are slightly curved, depressed in the early part, very short, slightly curved to almost straight in the later part, raised and beaded on the periphery, becoming depressed inward ; on the ventral side the sutures are straight, radial, and strongly depressed ; owing to the inward tilting of the dorsal surface of the last whorl the junction between the ventral and dorsal sutures can be seen from the the dorsal side ; umbilicus pentagonal in outline, wide, deep, and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate, except for the imperforate keel and tegilla ; surface rough, heavily papillose or even nodose, especially in the early part with the roughness decreasing gradually towards the last chamber ; the single marginal keel is distinctly beaded, with the beads slightly fading out on the penultimate and last chambers ; the keel of each chamber encircles its periphery and then disappears into the short, depressed, dorsal sutures ; the umbilicus is not bordered by a flange of any sort, although the large, scattered beads on the surface may simulate a beaded rim.

DIMENSIONS OF HOLOTYPE.

Maximum diameter = 0·54 mm.
Minimum diameter = 0·42 mm.
Maximum thickness = 0·34 mm. (Thickness of last chamber)
Minimum thickness = 0·23 mm. (Across middle part of test)

MAIN VARIATION.

1. Chambers on the dorsal side 13–18, most commonly 15, arranged in 2½–3 whorls, generally dextrally coiled.
2. Chambers in the last whorl 4½–6, slowly to moderately increasing in size.

REMARKS : *Globotruncana arabica* sp. nov. is distinguished by its large, concavo-convex, strongly umbilico-convex, single keeled test, its large umbilicus and rough surface. The only known *Globotruncana* species with a concavo-convex, umbilico-convex test are : *G. concavata* (Brotzen) 1934, from the Campanian–Santonian of Palestine, *G. repanda* Bolli 1957, from the Campanian of Trinidad, and *G. bahijae* sp. nov. from the Maestrichtian of the Esna–Idfu region. The first species is distinguished from *G. arabica* by its closely spaced double keel, less concave dorsal side, chambers which increase more rapidly in size, and by its smooth surface. The second is differentiated by its smaller test, fewer number of chambers, double keel in the early part (which may be absent in the penultimate and last chambers), much smaller early part, and less rugose surface. The third is distinguished by its less protruding ventral side and its double keel. *Globotruncana arabica* sp. nov. is morphologically closely related to *G. repanda* Bolli. Small specimens of *G. arabica* resemble *G. repanda*, but differ in having an entirely single keel, and chambers which increase slowly in size. By reduction of the ventral keel and increase in the size of test, in the number of chambers and in the surface rugosity, *G. repanda* might possibly have evolved into *G. arabica*. Such tendencies are clearly recorded in *G. repanda*, but the latter species is known to die out completely in the Upper Campanian, while *G. arabica* is only recorded from the Middle and Upper Maestrichtian. Thus it is suggested that *G. arabica* either evolved from a yet undescribed form, transitional between it and *G. repanda*, or that the latter also occurs in the Lower Maestrichtian, but has not yet been found.

Globotruncana arabica sp. nov. is also morphologically related to *G. lugeoni* Tilev and *G. youssefi* sp. nov. which occur in association with it. It is distinguished from the former by its larger test, its strongly shifted keel towards the dorsal side, its shorter, less curved, depressed dorsal sutures and its much wider umbilicus. It differs from the latter by the fact that *G. youssefi* has an almost flat dorsal side, or even slightly raised initial part, longer, more curved, raised and beaded dorsal sutures and a truly marginal keel.

HOLOTYPE. P.45515.

PARATYPES. P.45516.

HORIZON AND LOCALITY. Holo- and paratypes from sample No. 22, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. The species appears for the first time in the upper part of the Middle Maestrichtian *G. gansseri* Zone. It increases in number upwards in the section until it floods the uppermost part of this zone and the basal part of the overlying *G. esnehensis* Zone before dying out completely in the middle part of the latter zone.

Globotruncana arca (Cushman)

(Pl. 1, figs. 1*a*–2)

1926*a* *Pulvinulina arca* Cushman : 23, pl. 3, figs. 2*a–c*.
1927*a* *Globotruncana arca* (Cushman) Cushman : 91, pl. 19, figs. 11*a–c*.
1937*a* *Globotruncana arca* (Cushman) ; Glaessner : 36, pl. 1, figs. 10*a–c*.
1946 *Globotruncana arca* (Cushman) ; Cushman (pars) : 150, pl. 62, figs. 4*a–c* (non figs. 5*a–c*).
1951 *Globotruncana arca* (Cushman) ; Bandy : 509, pl. 75, figs. 1*a–c*.
1951 *Globotruncana arca* (Cushman) ; Noth : 77, pl. 8, figs. 15*a–c*.
1951*a* *Globotruncana arca* (Cushman) ; Nakkady (pars) : 56, pl. 1, figs. 4B–E, non fig. 4A.
1951 *Globotruncana arca* (Cushman) ; Tilev : 57, text-figs. 18*a–d*, 19*a–d*. (See also Tilev 1952, where figures are repeated.)
1953 *Globotruncana arca* (Cushman) ; Hagn : 97, pl. 8, figs. 11*a–c*, text-figs. 20, 21.
1953 *Globotruncana arca* (Cushman) ; Subbotina : pp. 185–188, pl. 9, figs. 1*a*–5*c*, pl. 10, figs. 1*a*–5*c*.
1955 *Globotruncana arca arca* (Cushman) ; Gandolfi (pars) : 63, pl. 5, figs. 3*a–c* ; non figs. 2*a–c*, 4*a–c*.
1956 *Globotruncana arca* (Cushman) ; Brönnimann & Brown : 539, pl. 23, figs. 10–12.
1957 *Globotruncana* (*Globotruncana*) *arca* (Cushman) ; Edgell (pars) : 110, pl. 3, figs. 4–6 ; non pl. 1, figs. 10–12.
1957 *Globotruncana arca* (Cushman) ; Bolli, Loeblich & Tappan : 44, pl. 11, figs. 6–11*c*.
1958 *Globotruncana arca* (Cushman) ; Bieda : 60, text-fig. 24.
1960 *Globotruncana arca* (Cushman) ; Vinogradov : 313, pl. 5, figs. 27*a–c*.
1962 *Globotruncana arca* (Cushman) ; Barr : 567, pl. 69, figs. 8*a–c*.

EMENDED DIAGNOSIS. A *Globotruncana* with large, robust, biconvex test ; great number of chambers per test and in last whorl ; two well-developed, much thickened beaded keels ; wide, inclined peripheral band ; curved, much thickened, raised, beaded sutures ; distinct, horseshoe-shaped ridge of beads outlining each chamber on ventral side ; wide umbilicus.

Description. (Pl. 1, figs. 1*a–c*). Test large, robust, unequally biconvex, coiled in a relatively high trochospire ; dorsal side convex, broadly arched, ventral side moderately inflated, slightly protruding ; equatorial periphery subcircular, moderately lobate ; axial periphery angular, slightly truncate, with two well-developed, strongly thickened marginal keels ; chambers on the dorsal side 22, arranged in $3\frac{1}{2}$ dextrally coiled whorls ; the initial ones are small, inflated, globigerine, increase very slowly in size and are followed by typically crescentic chambers ; the last whorl is composed of 7 (6+1 abortive), large, typically crescentic chambers (except for the fourth and fifth) which increase slowly in size ; on the ventral side these chambers are subglobular to ovoid, moderately inflated, sharply outlined by distinctly thickened horseshoe-shaped ridges ; sutures on the dorsal side curved, raised, thickened and beaded except on both sides of the antepenultimate chamber where they tend to be almost straight ; on the ventral side the sutures are short, thickened, raised, beaded and slightly curved forward ; umbilicus roughly hexagonal in outline, wide, deep, surrounded by raised ridges and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface smooth except for a few small, scattered papillae ; the two subparallel keels are well-developed, limbate and beaded, they enclose a relatively wide, depressed, inclined peripheral band except on the last chamber where the two keels become closer to each other ; the dorsal keel is more developed and strongly protruding while the ventral keel is slightly shifted towards the inner part of test.

Dimensions of described specimen.

Maximum diameter = 0·52 mm.
Minimum diameter = 0·46 mm.
Thickness = 0·27 mm.

Main variation.

1. Chambers on the dorsal side 18–24, arranged in 3–4 whorls, generally dextrally coiled.
2. The last whorl is composed of 5–8 chambers, but 6–7 is most common.

Remarks : *Globotruncana arca* (Cushman) was first described by Cushman (1926) as *Pulvinulina arca* n.sp. He later (1927) erected *Globotruncana* as a new genus, with *Pulvinulina arca* Cushman 1926, as type species.

Plummer (1931) described as *G. arca*, double- and single-keeled forms which differ from Cushman's original description and figures. Brönnimann & Brown (1956 : 450) stated that " Her two-keeled forms are specimens of *Glt. cretacea* Cushman which is an incipient *Glt. rosetta* (Carsey). Her one-keeled forms are actually double-keeled, but the two keels are very close together ; they are well-developed specimens of *Glt. rosetta*."

Cushman (1932) described as *G. arca*, a planoconvex, single-keeled form, and in 1946 he presented the figures of the holotype and of this form as *G. arca*. Cita (1948) interpreted Cushman's single-keeled form as *G. rosetta* (Carsey), while Bolli (1951) stated that it probably belongs to the *Globotruncana stuarti* group. Gandolfi (1955) made this form the basis of a new species which he named *Globotruncana bollii*, while Dalbiez (1955) considered it to belong to his subspecies *G. elevata stuartiformis* Dalbiez, [=*G. stuarti stuartiformis* Dalbiez].

Gandolfi (1955) described *Globotruncana arca caribica* as a new subspecies of *G. arca* (Cushman) and thus changed the latter's name to *G. arca arca* (Cushman). However, *G. arca caribica* appears to be a junior synonym of *G. gagnebini* Tilev 1951, thus the name *G. arca* (Cushman) is here retained. Similarly, Said & Kerdany (1961) described as *G. arca* (Cushman) from the Maestrichtian chalk of the Farafra Oasis, Egypt, a form which probably belongs to *G. gagnebini* Tilev.

Globotruncana arca (Cushman) is believed to have evolved from the *G. linneiana* (d'Orbigny) (=*G. lapparenti* Brotzen) stock as previously mentioned by Cita (1948), Bolli (1951), Brönnimann & Brown (1956) and Berggren (1962). On the other hand, *G. arca* was itself found to show three main evolutionary tendencies which are as follows :

1. A tendency towards the reduction of the ventral keel on the final chambers leading to *G. leupoldi* Bolli.
2. A tendency towards the flattening of the ventral side and the reduction of the ventral keel leading to *G. orientalis* sp. nov.
3. A tendency to reduce the size of test and the number of chambers in the last whorl leading to *G. convexa* Sandidge. (see Pl. 1, figs. 3*a*–*c*.)

The morphological characters and stratigraphical ranges of the five species (*G. linneiana*, *G. arca*, *G. leupoldi*, *G. orientalis* and *G. convexa*) support this hypothesis.

HYPOTYPES. P.45517.

HORIZON AND LOCALITY. Figured specimens Pl. 1 figs. 1*a*–*c*, 2, from sample No. 4, Abou Saboun section, and figs. 3*a*–*c*, from sample No. 23, W. El-Sharawna section.

STRATIGRAPHICAL RANGE : The species was first described from the upper part of the Papagallos shales (Mendez shale) of Mexico which was later considered to be of Maestrichtian age.

Analysis of all previous records of *G. arca* (Cushman) shows that it has a world-wide distribution, and that it occurs mainly in the Maestrichtian and the uppermost Campanian. However, owing to misidentification of the species and confusion with various other species, its true stratigraphical range has hitherto been obscured. Brönnimann & Brown (1956) stated that *G. arca* appears to be restricted to Maestrichtian strata and that all occurrences reported from pre-Maestrichtian strata are probably erroneous. They added that it is best developed in Upper Maestrichtian strata, and this was partially substantiated by Berggren (1962 : 51). However, *G. arca* was recorded by Barr (1962) from the uppermost part of the *Belemnitella mucronata* Zone of the Isle of Wight, England, and from the Upper Campanian of the Paris Basin by the present author.

In the Esna–Idfu region *G. arca* occurs as an abundant form in the *G. forncatai* Zone and in the lower part of the overlying *G. gansseri* Zone. It fades out gradually in the upper part of the latter zone, and dies out completely before the overlying *G. esnehensis* Zone.

Globotruncana bahijae sp. nov.

(Pl. 6, figs. 2*a*–*d*)

DIAGNOSIS. A *Globotruncana* with concavo-convex test, weakly developed double keel, wide peripheral band, rough surface and very wide umbilicus.

DESCRIPTION. Test large, roughly ovoid in outline, concavo-convex, coiled in a very low trochospire ; dorsal side gently concave with the early whorls depressed and the last chambers slightly sloping towards the central part of test, ventral side inflated and moderately protruding ; equatorial periphery roughly ovoid, moderately lobate with two widely spaced, delicately beaded marginal keels which are slightly masked by the surface rugosity ; axial periphery subrounded, subtruncate ; chambers on the dorsal side 15, arranged in 2½ dextrally coiled whorls ; the initial chambers are small, weakly inflated, globigerine, and increase slowly in size ; they are followed by relatively large, subglobular, compressed chambers which increase slightly more rapidly in size ; the last whorl is composed of 5½ large, crescentic, compressed chambers which are slightly tilted towards the central part and increase slowly in size ; on the ventral side the chambers are 5½, subglobular, slightly elongated in the direction of coiling, strongly inflated, moderately protruding, very loosely coiled and increase slowly in size ; sutures on the dorsal side slightly curved, depressed in the early part, strongly curved, raised and delicately beaded in the last whorl ; on the ventral side the sutures are straight, radial and strongly incised ; umbilicus hexagonal in outline, very wide, relatively shallow, covered by complex tegilla ; primary apertures interiomarginal, umbilical ; tegilla, with accessory apertures, reasonably well-preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface rough, covered with large papillae which are slightly reduced towards the last chamber ; the two marginal keels are delicately beaded, the dorsal one is always well-developed but the ventral is sometimes almost masked by the surface rugosity ; the two keels slightly diverge from each other and enclose an irregular, relatively wide peripheral band.

DIMENSIONS OF HOLOTYPE.

Maximum diameter = 0·45 mm.
Minimum diameter = 0·32 mm.
Thickness = 0·20 mm. (of last chamber)

MAIN VARIATION

1. Chambers on the dorsal side 13–18, arranged in 2½–3 whorls, usually dextrally coiled, but sinistral forms occasionally occur (of 67 specimens picked at random, 1 coiled sinistrally).
2. Chambers in the last whorl 5–7 increasing slowly to moderately in size.

REMARKS. *Globotruncana bahijae* sp. nov. is morphologically rather similar to each of the following *Globotruncana* species, all of which, except the last, appear in stratigraphically older strata :

1. *Globotruncana concavata* (Brotzen).
2. *Globotruncana fundiconulosa* Subbotina.
3. *Globotruncana* (*Rugoglobigerina*) *pennyi sunpennyi* Gandolfi.
4. *Globotruncana repanda* Bolli.
5. *Globotruncana arabica* sp. nov.

However, it is distinguished from *G. concavata* (Brotzen) by its more concave dorsal side and less protruding ventral one, widely spaced keels, chambers which increase less rapidly in size and rough surface.

It differs from *G. fundiconulosa* Subbotina in its more concave dorsal side, less strongly developed marginal keels, chambers which increase more rapidly in size and radial depressed ventral sutures.

It is more closely related to the form described by Gandolfi (1955) as *G.* (*Rugoglobigerina*) *pennyi subpennyi*, but differs from it in its concave dorsal side and less protruding ventral one and by its widely spaced marginal keels. It might possibly have evolved from the latter subspecies which appears to be a true *Globotruncana* (not a *Rugoglobigerina*), although Gandolfi's description does not allow a definite decision.

Globotruncana bahijae sp. nov. is distinguished from both *G. repanda* Bolli and *G. arabica* sp. nov. by its compressed test, less protruding ventral side, greater number of chambers and widely spaced keels.

HOLOTYPE. P.45518.

PARATYPES. P.45519.

HORIZON AND LOCALITY. Holo- and paratypes from sample No. 18 W. El-Sharawna section.

STRATIGRAPHICAL RANGE. The species appears for the first time in the middle part of the Middle Maestrichtian *G. gansseri* Zone. It increases in number upwards in the section to flood the upper part of the latter zone and then fades out gradually, disappearing completely before the overlying *G. esnehensis* Zone.

Globotruncana conica White

(Pl. 12, figs. 2*a–d*)

1928*b* *Globotruncana conica* White : 285, pl. 38, figs. 7*a–c*.

? 1950 *Globotruncana* (*Globotruncana*) sp. aff. *conica* White ; Reichel : 614, text fig. 7*b*.

? 1951 *Globotruncana conica* White ; Tilev : 67, figs. 22*a–d*. (See also Tilev 1952 where figures are repeated.)

1956 *Globotruncana conica* White ; Said & Kenawy : 150, pl. 5, figs. 16*a–c*.

EMENDED DIAGNOSIS. A *Globotruncana* with large, broadly conical test ; almost circular slightly lobate equatorial periphery, and angular to subangular axial one ; entirely single keel ; broadly conical dorsal side and flat to slightly concave ventral one ; numerous chambers and whorls, and large number of chambers in last whorl ; globigerine initial chambers and subcircular to crescentic intermediate ones, which become roughly rectangular in last whorl ; raised, beaded, almost straight dorsal sutures, and curved, depressed ventral ones ; ovoid overlapping chambers on ventral side and wide deep umbilicus.

DESCRIPTION. Test large, broadly conical ; dorsal side highly raised, with the various whorls arranged in the form of a cone with a rather sharp apex and a very broad base ; ventral side flat although the chambers are slightly inflated ; equatorial periphery almost circular, slightly lobate with a single, well-developed, beaded keel ; axial periphery subangular ; chambers on the dorsal side 24, arranged in 4 dextrally coiled whorls ; the initial chambers are very small, slightly inflated, globigerine and are followed by relatively larger chambers which are crescentic to semicircular and increase moderately in size ; the last whorl is composed of 6 large, roughly rectangular chambers which are elongated in the direction of coiling and increase slowly in size ; on the ventral side the chambers are 6, roughly ovoid to subcircular, slightly elongated, moderately inflated and overlapping especially in the later part ; sutures on the dorsal side slightly curved in the early part, almost straight and angular later, distinctly raised, thickened and beaded ; on the ventral side the sutures are depressed, generally curved forward in the later part, tending to be nearly radial in the early part, beaded and running in sutural depressions formed by the slight inflation of the chambers ; umbilicus circular, relatively wide, deep, surrounded by slightly raised, beaded ridges and covered by complex tegilla of which remnants are still preserved; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate except for the imperforate keel and tegilla ; surface smooth.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·51 mm.
Minimum diameter = 0·48 mm.
Thickness = 0·28 mm.

MAIN VARIATION.

1. Chambers 21–24, arranged in 3–4 whorls generally dextrally coiled (all studied specimens coiled dextrally).
2. Chambers in the last whorl 6–7, rarely 8.

REMARKS. *Globotruncana conica* was first described by White (1928), but his description was so short and incomplete that the species has often been misidentified, and its morphological characters and stratigraphical range much confused. The short description led most of the following authors to describe any *Globotruncana* species with a convex dorsal side and a flat ventral one as *G. conica* White. As a result, most of the existing figures are inadequate and most authors tend to speak of *G.* cf. *conica* White, rather than *G. conica* White.

Glaessner (1937*a*) and Keller (1946) described as *G* cf. *conica* White and *G. conica* White respectively, forms which possibly belong to *G. contusa* Cushman. The form described by Cushman & Renz (1947) as *G. conica* is doubtful, while that described by Cita (1948) can probably be assigned to *G. orientalis* sp. nov. Again, the form described by Bolli (1951) as *G. conica* White is probably *G. stuarti stuarti* (de Lapparent).

Tilev (1951, 1952) described as *G. conica* White, a form with only $5\frac{1}{2}$ chambers in the last whorl, and distinctly outlined chambers on the ventral side. This form is questionably related to the present species. However, the fact that Tilev included in the synonymy of his *G. conica,* forms such as *G. conica* var. *plicata* White and *G. linnei caliciformis* (de Lapparent), which are probably synonymous with *G. contusa contusa* (Cushman) and *G. contusa patelliformis* Gandolfi respectively, throws doubt on the identification of his specimens. Tilev also described as *G. conica-caliciformis* nom. nov., a form which he considered as transitional between *G. conica* White and *G. caliciformis* (de Lapparent). However, as mentioned above, *G. caliciformis* is a probable synonym of *G. contusa* (Cushman), a species which is morphologically distinct from *G. conica.* This intermediate form described by Tilev may belong to *G. orientalis* sp. nov.

Subbotina (1953) described as *G. conica* White, forms which are *G. contusa scutilla* Gandolfi and *G. contusa patelliformis* Gandolfi.

Gandolfi (1955) considered *G. conica* White as a subspecies of *G. stuarti* (de Lapparent), and thus changed its name to *G. stuarti conica* (White). However, as mentioned under *G. stuarti stuarti,* the morphological characters and stratigraphical ranges of the two species warrant their separation. Moreover, the form described by Gandolfi (1955) is different from both the holotype of White and the known forms of *G. stuarti,* and should be renamed and redescribed in more detail. Following Gandolfi (1955), Said & Kenawy (1956) incorrectly emphasized the relationship between *G. conica* White and *G. stuarti* (de Lapparent).

Pessagno (1960, 1962) described as *G. conica* White, forms which were said to have a double keel on the early chambers of the last whorl, giving way to a single keel on the following chambers. Such forms probably belong to *G. orientalis* sp. nov.

Globotruncana conica White is unique among the known spiroconvex *Globotruncana* species. No morphologically similar forms have yet been recorded from older strata, and thus very little is known about the evolutionary history of the species. However, it is possible that *G. conica* evolved from either *G. sharawnaensis* sp. nov. or *G. orientalis* sp. nov. The confused stratigraphical range of the species makes it difficult to decide, for the time being, although forms of *G. sharawnaensis* with an entirely single keel appear closely similar to *G. conica.*

HYPOTYPE. P.45520.

HORIZON AND LOCALITY. Figured specimen from sample No. 16, Gebel Owaian section.

Stratigraphical range. White (1928) described *G. conica* from the Maestrichtian Mendez formation of Mexico. However, he stated that the species ranges from the lower to the uppermost Cretaceous (Tamaulipas–Mendez formations) of Mexico, which is rather strange, as most of these *Globotruncana* species have very short ranges. Apparently he had confused the species with superficially similar *Globotruncana* and *Praeglobotruncana* species which occur in older strata. *Globotruncana conica* was later described from the Middle and Upper Maestrichtian of S.E. Turkey (Tilev 1952) and form the Maestrichtian of northern Sinai, Egypt (Said & Kenawy 1956). It was also stated to occur in the Maestrichtian of northern Italy (Cita 1948, 1955, and Bolli & Cita 1960*a*) ; from the Upper Santonian–Lower Campanian of Trinidad (Bolli 1957, where the same author also recorded a form he described as *G.* cf. *conica* White in the Campanian–Maestrichtian of the same area) ; and from the upper part of the Mendez shale of Mexico (Hay 1960).

In the Esna–Idfu region *G. conica* White is rare to common in the Middle Maestrichtian *G. gansseri* Zone.

Globotruncana contusa contusa (Cushman)

(Pl. 7, figs. 2*a*–3*c*; Pl. 11, figs. 1*a*, *b*)

1926*a* *Pulvinulina arca* Cushman var. *contusa* Cushman : 23 (no figs.).
1927*a* *Globotruncana arca* Cushman var. *contusa* (Cushman) ; Cushman : 169 (no figs.).
1939 *Globotruncana arca* (Cushman) var. *contusa* (Cushman) ; Morozova : 80, pl. 1, figs. 1–3.
1946 *Globotruncana arca* (Cushman) var. *contusa* (Cushman) ; Cushman : 150–151, pl. 62, figs. 6*a*–*b*.
? 1946 *Globotruncana conica* White ; Keller : 102–103, pl. 3, figs. 4, 5.
1948 *Globotruncana arca* (Cushman) var. *contusa* (Cushman) ; Di Napoli : 21–22, text-figs. 2*a*–*c*.
1951 *Globotruncana* (*Globotruncana*) *contusa* (Cushman) ; Noth : 79, pl. 8, figs. 17*a*–*c*.
1951 *Globotruncana contusa* (Cushman) ; Bolli : 196, pl. 34, figs. 7–9, text-fig. 1*f*.
1953 *Globotruncana contusa* (Cushman) ; Subbotina (pars) : 192–194, pl. 2, figs. 3*a*–*c* ; pl. 12, figs. 2*a*–*c* (non figs. 1*a*–*c*).
? 1954 *Globotruncana contusa* (Cushman) ; Nakkady & Osman : 78–79, text-figs. A*a*–*c*.
1955 *Globotruncana contusa contusa* (Cushman) ; Gandolfi : 53, pl. 4, figs. 3*a*–*c*.
1956 *Globotruncana contusa* (Cushman) ; Wicher : 136, pl. 12, figs. 5, 6.
1956*a* *Marginotruncana contusa* (Cushman) Hofker : 53, text-fig. 9.
1960*a* *Globotruncana* (*Marginotruncana*) *contusa* (Cushman) ; Hofker : 225, text-figs. 22*a*–*c*.
? 1960*e* *Globotruncana contusa* (Cushman) ; Hofker : 586, text-fig. 1, drawing No. 15.
1960 *Globotruncana contusa* (Cushman) ; Olsson : 50, pl. 10, figs. 25, 26.
1960 *Globotruncana contusa* (Cushman) ; Vinogradov : 311, pl. 4, figs. 23*a*–24*c* ; pl. 5, figs. 25*a*–*c*.
? 1962 *Globotruncana* (*Marginotruncana*) *contusa* (Cushman) ; Hofker : 1062, text-fig. 7A.

Emended diagnosis. A *Globotruncana* with large highly spiroconvex test, distinctly folded surface, roughly angular, polygonal periphery, flat to slightly concave ventral side, sharply cut rectangular chambers on ventral side, radial, depressed ventral sutures, two well-developed marginal keels and almost horizontal peripheral band.

DESCRIPTION. (Specimen, Pl. 7, figs. 2*a–c*). Test large, robust, spiroconvex with a sharply angular, polygonal outline and a peculiarly shaped, folded surface ; dorsal side highly trochospirally coiled, with bluntly curved convex folds radiating from the apex and shallowly concave, broader depressions running between the radiating folds, and widening away towards the base ; ventral side concave ; equatorial periphery roughly pentagonal with blunt corners, gently undulating and very weakly, if at all, lobate ; periphery with two well-developed, heavily beaded keels, enclosing a relatively wide, almost horizontal, slightly depressed peripheral band ; axial periphery subangular, distinctly truncate ; chambers, on the dorsal side 23, arranged in 4 dextrally coiled whorls ; they increase moderately and regularly in size till shortly before the beginning of the last whorl where they start to enlarge very rapidly and to change in shape ; the initial chambers are small, inflated, globigerine ; they increase moderately in size and are followed by relatively large, globular, inflated chambers which increase more rapidly in size, and become highly undulating and strongly elongated in the direction of coiling towards the end of the penultimate whorl ; the last whorl is composed of 4, very long, very narrow, broadly curved, roughly oblong, undulating chambers which are extremely elongated in the direction of coiling ; on the ventral side the chambers are 4, very large, angular, roughly oblong, very narrow, strongly elongated in the direction of coiling with their surfaces gently sloping towards the umbilicus ; sutures on the dorsal side slightly curved, faintly raised and delicately beaded in the early part, strongly curved, undulating, raised, thickened and heavily beaded later ; on the ventral side the sutures are straight, radial and depressed ; umbilicus rhombodial in outline, relatively wide, deep, surrounded by beaded umbilical ridges and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla, with accessory apertures, only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface delicately papillose especially on the early part and on the ventral side.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·70 mm.
Minimum diameter = 0·50 mm.
Thickness = 0·45 mm.

MAIN VARIATION.

1. Chambers 16–25, arranged in 3–4 or rarely 5 whorls, usually dextrally coiled, but sinistral forms also occur (out of 25 specimens picked at random, 1 coiled sinistrally).
2. Chambers in the last whorl 4–5.
3. The two keels are either equally developed throughout or the ventral one becomes slightly reduced on the last chamber.

REMARKS. *Globotruncana contusa contusa* was first described by Cushman (1926) as a variety of *Pulvinulina arca* Cushman = *Globotruncana arca* (Cushman), but no figures were given until 1946, when Cushman figured the dorsal and lateral views of the holotype.

Glaessner (1937*a*) raised Cushman's variety to specific rank, but again gave no figures. He was followed by Cita (1948), Bolli (1951), Noth (1951), Subbotina (1953), Ayala (1954), Nakkady & Osman (1954) and Troelsen (1955), but the figures given by both the first and last authors are different from Cushman's holotype.

Gandolfi (1955) described two new subspecies of *G. contusa* (Cushman) and thus changed its name to *G. contusa contusa*, to distinguish it from *G. contusa patelliformis* Gandolfi and *G. contusa scutilla* Gandolfi. Hofker (1956*a*, 1960*a*, 1962*a*) assigned the present from to his genus *Marginotruncana* which is a junior synonym of *Globotruncana* as stated above. *Globotruncana conica* var. *plicata* White 1928 is probably a junior synonym of G. *contusa contusa* (Cushman), but White's brief description does not allow a definite decision without examination of his holotype. Similarly, comparison of oriented thin sections of *G. contusa* (Cushman) with the holotype of *Rosalina linnei* mut. *caliciforme* de Lapparent 1918, and with *Globotruncana linnei caliciformis* (de Lapparent) of Vogler (1941), showed the possibility that *G. contusa* (Cushman) 1926 may be a junior synonym of *G. caliciformis* (de Lapparent) 1918. However, examination of several samples from the type locality of de Lapparent (The Hendaye region of southwestern France) is needed before any decision can be taken, as his original description is very brief, and his figure is only of a thin section. On the other hand, forms described as *G. caliciformis* by authors are different from the holotype of de Lapparent (1918) and the hypotype of Vogler (1941), and should be renamed and redescribed in more detail. Similarly, *G. contusa* (Cushman) of Troelsen (1955) is different from the holotype of Cushman (1926), and should also be renamed and redescribed ; the form figured by Berggren (1062) as *G. contusa* is doubtfully related to Troelsen's form, and is completely different from the holotype of Cushman.

Globotruncana contusa contusa (Cushman) is believed to have evolved from *G. fornicata fornicata* Plummer through *G. contusa witwickae* subsp. nov. as suggested by the morphological characters and stratigraphical ranges of these forms. However Gandolfi (1955) suggested the evolution of *G. contusa contusa* (Cushman) from *G. contusa patelliformis* Gandolfi although he admitted its relationship to *G. fornicata fornicata* Plummer.

HYPOTYPES. P.45521.

HORIZON AND LOCALITY. Figured specimens, from sample No. 18, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. *Globotruncana contusa contusa* (Cushman) was described from the Maestrichtian Mendez shale of Mexico, and was later recorded from the same formation by Cushman (1927, 1946), White (1928), and Hay (1960). It was also recorded from the Maestrichtian of the U.S.S.R. (Morozova 1939, Keller 1946, Subbotina 1953) ; the Campanian–Maestrichtian of Austria and Switzerland (Noth 1951) ; the Maestrichtian of Trinidad (Bolli 1951, 1957*a*) ; the Maestrichtian of Qabeliat and the Campanian–Maestrichtian of the Sudr sections, Sinai, Egypt (Nakkady & Osman 1954) ; the Maestrichtian Colon shale of northeastern Colombia

(Gandolfi 1955) ; the Lower and Upper Maestrichtian of the Gamsa Basin, Austria (Wicher 1956) ; the Lower–Upper Maestrichtian boundary, Cr_4–Mb, at Leon, Belgium (Hofker 1956*a*) ; the Lower and Upper Maestrichtian of the Atlantic Coastal Plain (Olsson 1960) ; the Maestrichtian of the Prahova Basin, Romania (Vinogradov 1960) ; and from the type Maestrichtian of Holland (Hofker 1960*a*, 1962*a*).

In the Esna–Idfu region, *G. contusa contusa* appears in the basal part of the *G. gansseri* Zone. It gradually increases in numbers upwards in the section, to flood this zone, and then fades out gradually, dying out completely in the overlying *G. esnehensis* Zone. No typical representatives of this subspecies were recorded in the Lower Maestrichtian *G. fornicata* Zone, which is flooded with transitional stages between the *G. fornicata* and *G. contusa* groups (e.g. *G. contusa witwickae*) ; while only rare forms were recorded throughout the *G. esnehensis* Zone.

All reliable references show that *G. contusa contusa* ranges throughout the Middle and Upper Maestrichtian. All records of this subspecies from rocks older than the Middle Maestrichtian are probably confused with one of the other subspecies or are erroneous.

Globotruncana contusa patelliformis Gandolfi

(Pl. 8, figs. 1*a–c*)

1955 *Globotruncana* (*Globotruncana*) *contusa patelliformis* Gandolfi : 54–55, pl. 4, figs. 2*a–c*.
1961 *Globotruncana contusa* cf. *patelliformis* Gandolfi ; Corminboeuf : 112, pl. 1, figs. 1*a–c*.

Description. Test large, robust ; trochospiraly coiled in the form a of high, truncated cone with a subcircular, wide base ; dorsal side very highly raised, and distinctly coned ; ventral side flat or even slightly concave as the sides gently slope towards the umbilicus ; equatorial periphery almost circular, slightly lobate, with two well-developed, heavily beaded marginal keels which become much closer on the penultimate chamber and reduced to a single, limbate, non-beaded keel on the last one ; the two keels enclose an almost horizontal and relatively wide peripheral band which is gradually reduced towards the last chamber ; axial periphery subangular, truncate ; chambers on the dorsal side are not all clear, probably 14 in number, arranged in 3 dextrally coiled whorls ; initial chambers small, indistinct, roughly globular, weakly inflated, increasing slowly in size and followed by crescentic, inflated chambers which are strongly elongated in the direction of coiling and increasing very rapidly in size ; the last whorl is composed of 4 very long, narrow, slightly undulating, crescentic chambers which are distinctly elongated in the direction of coiling and increasing slowly in size ; on the ventral side the chambers are 4, very long, narrow, distinctly elongated and strongly overlapping ; the very long sutures on the dorsal side are distinctly curved, strongly raised and heavily beaded especially in the early part ; on the ventral side the sutures are short, strongly curved forward, raised and beaded ; umbilicus roughly rectangular in outline, wide, deep, surrounded by raised, beaded ridges and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal umbilical ; tegilla, with accessory apertures, only poorly preserved ; wall calcareous, perforate, except for the imperforate keels, peripheral band and tegilla ; surface generally smooth but with a few scattered papillae on the dorsal side especially in the early part.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·52 mm.
Minimum diameter = 0·49 mm.
Thickness = 0·40 mm.

MAIN VARIATION.

1. Chambers 14–21, arranged in 3–4 whorls, which are generally dextrally coiled (all the specimens studied coiled dextrally).
2. Chambers in the last whorl 4–5, most commonly 4, slightly to moderately undulate and slowly to moderately increasing in size ; the last chamber is sometimes slightly smaller than the penultimate.

REMARKS. *Globotruncana contusa patelliformis* is distinguished from *G. contusa contusa* by its more regular, far less plicated, subconical test ; its narrow elongate, fornicata-type chambers on the ventral side ; strongly curved forward, raised and beaded ventral sutures and distinctly elongate early chambers. It is also distinguished from the other members of the *G. contusa* group by the shape of its ventral chambers and sutures and its robust, regular test.

Globotruncana contusa patelliformis is believed to have evolved from *G. fornicata fornicata* Plummer through *G. adamsi* sp. nov., as suggested by their morphological characters and stratigraphical distribution. The early part of *G. contusa patelliformis* closely resembles *G. adamsi*, and the ventral side of the two forms is also very similar. However, Gandolfi (1955) suggested the evolution of *G. contusa patelliformis* from *G. contusa scutilla* which can be considered a very small *G. contusa patelliformis*, but no transitional stages between these two subspecies were recorded in the present study. Gandolfi also suggested that *G. contusa patelliformis* had evolved into *G. contusa contusa* (Cushman) by the development of the sharply cut polygonal periphery, plicated dorsal side, and depressed ventral sutures.

Specimens of *G. contusa patelliformis* Gandolfi, from the Esna–Idfu region, conform well with the original description and figures of the holotype, and with topotypes kindly forwarded to the present author by Dr. R. Gandolfi.

HYPOTYPE. P.45522.

HORIZON AND LOCALITY. Figured specimen from sample No. 18, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. Gandolfi (1955) described *G. contusa patelliformis* from the Colon shale of northeastern Colombia, and gave its range as Campanian–Maestrichtian. However, analysis of the planktonic Foraminifera of the Colon shale, described by Gandolfi, suggests a Maestrichtian age for the whole formation.

Corminboeuf (1961) recorded the present subspecies from the Maestrichtian of Switzerland.

In the Esna–Idfu region, *G. contusa patelliformis* occurs in the basal part of the Middle Maestrichtian *G. gansseri* Zone, where it increases gradually upwards in the section to flood the middle and upper parts of this zone and then fades out gradually in the overlying *G. esnehensis* Zone before dying out completely in the upper part of the latter zone.

Globotruncana contusa scutilla Gandolfi

1955 *Globotruncana* (*Globotruncana*) *contusa* (Cushman) *scutilla* Gandolfi : 54, pl. 4, figs. 1*a–c*.

REMARKS. A few specimens referable to the present subspecies were recorded from the *G. fornicata* Zone. Morphologically they appear to be so closely similar to *G. contusa patelliformis* that they could be considered small forms of it, despite the great difference in size. However, as it was only recorded from the *G. fornicata* Zone of the sections studied, and was stated by Gandolfi (1955) to appear in northeastern Colombia much earlier in the succession than *G. contusa patelliformis* (the former appears in the Coniacian while the latter appears in what he considered Campanian), it was found advisable to treat it separately.

G. contusa scutilla (if treated separately from *G. contusa patelliformis*) is believed to have evolved from *G. fornicata fornicata* (Plummer) into *G. contusa patelliformis* Gandolfi.

HYPOTYPE. P.45523.

STRATIGRAPHICAL RANGE. Gandolfi (1955) recorded the present subspecies as ranging throughout the upper part of the Manaure shale and the basal part of the Colon shale of northeastern Colombia, which he considered as Coniacian–Lower Campanian. However, as previously mentioned, all the Colon shale is probably Maestrichtian in age.

In the Esna–Idfu region *G. contusa scutilla* occurs as common to rare in the Lower Maestrichtian *G. fornicata* Zone only.

Globotruncana contusa witwickae subsp. nov.

(Pl. 7, figs. 1*a–c*)

DIAGNOSIS. A *Globotruncana contusa* (Cushman) with much lower spire, less plicated surface and less elongated chambers on dorsal side.

DESCRIPTION. Test large, robust, spiroconvex, coiled in a relatively high trochospire ; dorsal side moderately convex, gently plicate and undulate ; ventral side almost flat and weakly inflated ; equatorial periphery bluntly polygonal, with two well-developed, heavily beaded, marginal keels which enclose a narrow, slightly inclined peripheral band and tend to weaken towards the last chamber where the ventral keel is completely reduced ; axial periphery subangular, subtruncate ; chambers on the dorsal side 17, arranged in 3 dextrally coiled whorls ; initial chambers very small, globular, weakly inflated, increasing very slowly in size, followed by much larger, subglobular, inflated chambers which tend to be roughly crescentic towards the last whorl and which increase moderately in size ; the last whorl composed of 5 large, narrow, distinctly elongated chambers, roughly crescentic in the early part, irregular, folded and undulate in the last two chambers, which increase moderately in size although the last chamber is slightly smaller than the penultimate ; the 5 chambers on the ventral side are large, angular, roughly rectangular, strongly elongated and increase moderately in size except for the last one ; sutures on the dorsal side short, curved, beaded in the early part and distinctly elongated, curved, undulated, raised, thickened and beaded later ; on the ventral side the sutures are slightly curved in the early part, straight, radial and depressed in the later ; umbilicus roughly stellate in outline, relatively wide, deep, bordered by thick beaded ridges which fade out gradually towards the last chamber ; it is covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla, with accessory apertures, only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface delicately papillose, especially in the early part and on the ventral side.

DIMENSIONS OF HOLOTYPE.

Maximum diameter = 0·70 mm.
Minimum diameter = 0·54 mm.
Thickness = 0·31 mm.

REMARKS. This form represents the maximum development of a whole series of transitional stages between *G. fornicata fornicata* Plummer and *G. contusa contusa* (Cushman). It could neither be included in the former species, although it occurs with it, nor in the latter as it is morphologically slightly different and stratigraphically older. It is more closely related to *G. contusa contusa* (Cushman) of which it is therefore considered a subspecies.

Pozaryski & Witwicka (1956) mentioned the occurrence of what they described as *G. fornicata* var. *contusa* in the Upper Campanian of the Lublin Basin, central Poland, but gave no figure or description. Their form may belong to the present subspecies or it may be transitional to *G. fornicata fornicata* Plummer. However, as all forms of *G. fornicata* which show transitional characters to *G. contusa* are included in the present subspecies, Pozaryski & Witwicka's form is considered to belong here. This subspecies is named after Dr. E. Witwicka of the Geological Institute, Rakowiecka, Poland.

HOLOTYPE. P.45524.

PARATYPES. P.45525.

HORIZON AND LOCALITY. Holotype and paratypes, from sample No. 4, Abou Saboun section.

STRATIGRAPHICAL RANGE. The subspecies is restricted in the present sections to the Lower Maestrichtian *G. fornicata* Zone, where it is common to abundant. The form described by Pozariski & Witwicka (1956) as *G. fornicata* var. *contusa* which probably belongs to the present subspecies, was recorded from the Upper Campanian of central Poland. Records of *G. contusa contusa* (Cushman) from rocks older than the Middle Maestrichtian may be of *G. contusa witwickae.*

***Globotruncana* cf. *convexa* Sandidge**

(Pl. 1, figs. 5*a–c*)

1932 *Globotruncana convexa* Sandidge : 285, pl. 44, figs. 9–11.

Description. Test small, biconvex, coiled in a low trochosphire ; dorsal side, moderately arched, ventral side weakly inflated and slightly protruding ; equatorial periphery roughly ovoid or rather quadrate, distinctly lobate, with two well-developed, heavily beaded keels enclosing a wide, inclined peripheral band ; axial periphery truncate ; chambers on dorsal side 15, arranged in 3 dextrally coiled whorls ; the initial chambers are very small, globigerine, inflated and increase slowly in size ; the last whorl is composed of 4 large, crescentic chambers which are distinctly flattened, elongated in the direction of coiling and increase moderately in size ; on the ventral side the chambers are 4, large, ovoid, weakly inflated and slightly overlapping ; sutures on the dorsal side curved, raised and heavily beaded ; on the ventral side the sutures are strongly curved forward, slightly raised and beaded ; umbilicus roughly quadrangular in outline, wide, deep, bordered by raised, beaded ridges and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface delicately papillose in the early part, becoming smoother towards the last chamber.

Dimensions of described specimen.

Maximum diameter	=	0·40 mm.
Minimum diameter	=	0·30 mm.
Thickness	=	0·17 mm.

Remarks. Cushman & Hedberg (1941) followed by Cushman & Deaderick (1944), Cushman (1946), Cita (1948), Hagn (1953) and Graham & Clark (1961) considered *G. convexa* Sandidge to be a junior synonym of *G. fornicata* Plummer. However, as can be seen from the original description and figures of Sandidge (1932) and from the samples here studied, *G. convexa* is more closely related to *G. arca* (Cushman) than to *G. fornicata* Plummer and should be considered separately.

The specimens here described as *G.* cf. *convexa* Sandidge differ from the holotype in being less convex on the dorsal side and in having slightly raised ventral sutures. Sandidge described the ventral keel on the holotype as poorly developed, while on the specimen here figured the two keels are both well-developed, although the tendency towards a less developed ventral keel was clearly observed.

Globotruncana convexa is believed to have evolved from *G. arca* (Cushman) by a reduction in size of test and in the number of chambers, and by the development of surface rugosity.

Hypotype. P.45526.

HORIZON AND LOCALITY. Figured specimen, from sample No. 20, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. *Globotruncana convexa* was first recorded by Sandidge (1932) from the Maestrichtian Ripley formation of Alabama.

In the Esna–Idfu region *G.* cf. *convexa* ranges throughout the Maestrichtain, being common to abundant in the *G. fornicata* and the *G. gansseri* Zones, gradually fades out towards the top part of the latter zone and completely dies out in the overlying *G. esnehensis* Zone.

Globotruncana esnehensis Nakkady & Osman

(Pl. 12, figs. 1*a–d*)

1950 *Globotruncana arca* (Cushman) *var. esnehensis* Nakkady : 690, pl. 90, figs. 23–26.
1954 *Globotruncana esnehensis* Nakkady & Osman : 79, pl. 19, figs. 3*a*–c.
? 1956*b* *Marginotruncana stuarti* (de Lapparent) ; Hofker : 332–333, text-fig. 23.
1956 *Globotruncana caliciformis* Vogler ; Said & Kenawy : 150, pl. 5, figs. 18*a–c*.
1956 *Globotruncana intermedia* Bolli ; Said & Kenawy : 151, pl. 5, figs. 15*a–c*.
1961 *Globotruncana esnehensis* Nakkady, Said & Kerdany : 331, pl. 2, figs. 12*a–c*.

EMENDED DIAGNOSIS. A *Globotruncana* with large, spiroconvex test ; broadly-domed dorsal side and flat to slightly convex or even slightly concave, undulating ventral one ; well-developed beaded, single keel ; chambers increasing slowly in size, almost petaloid on dorsal side and subglobular to ovoid on ventral side ; slightly curved, raised, beaded dorsal sutures and radial depressed ventral ones ; large umbilicus and distinctly beaded umbilical ridge ; slightly to moderately lobulate equatorial periphery and angular, acute axial one; peculiar apertural face of last chamber and delicately papillose surface.

DESCRIPTION. Test large, almost circular in outline, spiroconvex, coiled in a relatively high trochospire ; dorsal side broadly domed ; ventral side almost flat or even slightly concave, although the chambers are weakly inflated ; equatorial periphery circular, moderately lobate with a single well-developed, beaded keel ; axial periphery angular, acute ; chambers on the dorsal side 19, arranged in three whorls which are coiled dextrally and very tightly ; they increase slowly and regularly in size, except the last, which is slightly smaller than the penultimate ; initial chambers small, inflated, globigerine, followed by relatively large, subglobular, moderately inflated ones ; the last whorl is composed of 6 large, typically petaloid chambers which moderately overlap and increase slowly in size ; on the ventral side the chambers are 6, large, roughly ovoid, slightly inflated and increase so slowly in size that they all appear to be roughly equal ; each chamber is weakly inflated at its centre and slopes gently towards the suture on each side giving the ventral surface a gently undulating appearance ; sutures on the dorsal side are very slightly curved or almost straight in the early part, very gently curved in the later part, raised and distinctly beaded ; on the ventral side they are radial, depressed and delicately beaded ; umbilicus hexagonal in outline, wide, relatively deep, surrounded by a beaded umbilical ridge and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate except for the imperforate keel and tegilla ; surface delicately papillose especially on the early part and on the ventral side.

DIMENSIONS OF DESCRIBED SPECIMEN.
Maximum diameter = 0·50 mm.
Minimum diameter = 0·44 mm.
Thickness = 0·27 mm.

MAIN VARIATION.

1. Chambers 15–21, arranged in 3–4 whorls usually dextrally coiled, but sinistral forms also occur (out of 500 specimens selected at random, 28 coiled sinistrally).
2. The last whorl is composed of 5–7 chambers, normally 6, varying in shape from typically petaloid to slightly elongate or even roughly rectangular, and in the degree of inflation on the ventral side which may give it a weakly or distinctly undulating appearance.

REMARKS. *Globotruncana ensehensis* was first described by Nakkady (1950) as a variety of *Globotruncana arca* (Cushman). Nakkady & Osman (1954) realizing the great difference between this form and *G. arca* (Cushman), quite justifiably raised it to specific rank. Hofker (1956*c*: 75) and Berggren (1962 : 31) considered *G. esnehensis* as a junior synonym of *Abathomphalus intermedia* (Bolli), but the two species are too remote to be related to each other. Again, Said & Kenawy (1956) described as *G. intermedia* Bolli, and *G. caliciformis* Vogler, forms which are actually *G. esnehensis*.

The evolutionary history of *G. esnehensis* is not clearly known because its stratigraphical range has been somewhat confused. However, its morphological similarity to both *G. orientalis* sp. nov. and *G. fareedi* sp. nov., which appear earlier in the section, may suggest its evolution from one of these species, although no direct evidence was recorded. Again, it is possible that *G. esnehensis* has evolved from *G. conica* White, although the morphological characters and stratigraphical range of the latter species have been very much confused.

Specimens of *G. esnehensis*, from the Esna–Idfu region, conform well with the holotype of *G. arca* (Cushman) var. *esnehensis* of Nakkady (1950) (B.M.N.H., P.41780), the paratypes (P.41781), and with the description and figures of Nakkady & Osman (1954).

HYPOTYPE. P.45527.

HORIZON AND LOCALITY. Figured specimen, from sample No. 17, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. Nakkady (1950) described *G. arca* (Cushman) var. *esnehensis* from the Maestrichtian Esna shale of the Abu Durba section, western Sinai, Egypt. He also reported it to be frequent in the Maestrichtian *Globotruncana–Guembelina* Zone of the Abu Durba and Mellaha sections and to flood the Maestrichtian chalk of Gebel Duwi.

Nakkady & Osman (1954) described *G. esnehensis* from the Campanian–Maestrichtian of southern and western Sinai, Egypt and it was recorded from the Maestrichtian of northern Sinai (Said & Kenawy 1956), the Maestrichtian of the Farafra Oasis (Said & Kerdany 1961) and from the Lower Maestrichtian of northwestern Germany and Holland (Hofker 1956*b*).

In the Esna–Idfu region *G. esnehensis* appears in the basal part of the Middle Maestrichtian *Globotruncana gansseri* Zone as a common form, increases gradually upwards in the section, flooding the upper part of the Maestrichtian and characterizing the *Globotruncana esnehensis* Zone, the upper part of which is truncated by the disconformity separating it from the overlying basal Tertiary rocks.

Globotruncana fareedi sp. nov.

(Pl. 9, figs. 4*a–d*)

? 1946 *Globotruncana rosetta* (Carsey) ; Keller : 102, pl. 2, figs. 17–19, pl. 3, fig. 6.
? 1955 *Globotruncana rosetta insignis* Gandolfi : 67, pl. 6, figs. 2*a–c*.
1956 *Globotruncana falsostuarti* Sigal ; Knipscheer : 54, pl. 4, figs. 13*a*, *b*, 16*a–c*, text-fig. 4.

DIAGNOSIS. A *Globotruncana* with large, circular, biconvex test ; distinctly lobate periphery ; characteristic, roughly quadrangular chamber shape on both sides ; entirely single keel ; short, nearly radial, depressed, sutures on ventral side ; raised, thickened, beaded, imbricate umbilical ridges, and wide, peculiarly-shaped umbilicus.

DESCRIPTION. Test large, circular, biconvex ; dorsal side arched ; ventral side moderately protruding ; periphery circular, distinctly lobate, transversally acute, with a single well-developed, beaded keel ; chambers on the dorsal side 18, arranged in 3 dextrally coiled whorls ; initial chambers small, inflated, globigerine, followed by roughly quadrangular chambers which increase regularly in size ; the last whorl is composed of 6 large, quadrangular chambers which are very slightly elongated in the direction of coiling ; on the ventral side the 6 large, roughly quadrangular chambers are moderately inflated especially around the umbilicus, and taper out gradually towards the periphery ; sutures on the dorsal side slightly curved in the early part, nearly straight in the last part, raised and beaded ; on the ventral side the sutures are very slightly curved or nearly straight, radial and strongly depressed especially towards the periphery, while towards the umbilicus they are slightly raised, thickened and beaded before curving around the umbilicus and joining to form a much thickened, raised, beaded umbilical flange ; umbilicus wide, deep, roughly hexagonal, covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate, except for the imperforate keel and tegilla ; surface smooth and finely porous.

DIMENSIONS OF HOLOTYPE.

Maximum diameter	=	0·47 mm.
Minimum diameter	=	0·44 mm.
Maximum thickness	=	0·22 mm.

MAIN VARIATION.

1. The test may be strongly or weakly biconvex.
2. Chambers 18–24 arranged in 3–4 whorls, (all the specimens studied coiled dextrally).
3. The beading of the sutures and the keel may be heavy throughout or may fade out gradually towards the last chamber.
4. The rate of growth may be slow and constant, leading to a regular increase in chamber size, or it may be rapid in the later stage, producing relatively bigger chambers in the last whorl.
5. The dorsal surface of each of the chambers in the last whorl (not the dorsal side of the test) is flat, slightly convex, or even slightly concave.
6. The umbilicus is moderate to large and the ventral sutures are either slightly or strongly depressed.

REMARKS. *Globotruncana fareedi* sp. nov. morphologically resembles both *G. stuarti stuarti* (de Lapparent) and *G. esnehensis* Nakkady & Osman. It is distinguished from the former by its equally biconvex test, lobate periphery, quadrangular rather than trapezoidal chambers on the dorsal side ; short, depressed radial sutures on the ventral side and less tangential ones on the dorsal ; its much wider umbilicus and imbricate umbilical flange. It differs from *G. esnehensis* in having a biconvex test, a much lower dorsal side and a more protruding ventral one, quadrangular chambers on the ventral side and less inflated ones on the dorsal, much wider umbilicus and an imbricate umbilical flange. *Globotruncana falsostuarti* Sigal has a similarly wide umbilicus and discontinuous umbilical flange, but is distinguished by its double keel and more protruding ventral side.

Globotruncana fareedi sp. nov. was probably confused in the past with both *G. rosetta rosetta* (Carsey) and *G. falsostuarti* Sigal. However, *G. rosetta rosetta* is distinguished by its perfectly plano-convex, umbilico-convex test ; double keel on the early chambers of the last whorl, becoming single on the last chambers; its flat crescentic chambers on the dorsal side, and angular conical, strongly protruding ones on the ventral ; its narrower umbilicus, and slightly rougher surface. The forms described as *G. rosetta* (Carsey) by Keller (1946) and as *G. rosetta insignis* by Gandolfi (1955) are not related to *G. rosetta*, but probably belong to the present species, although Gandolfi's form shows a flatter dorsal side and a slightly narrower umbilicus. Again, *G. falsostuarti* Sigal was so briefly described that its diagnostic features were not really known, and thus it has often been misinterpreted. The forms figured by Knipscheer (1956) as *G. falsostuarti* are different from Sigal's holotype, but may well belong to the present species, while the form described as *G. rosetta pembergeri* by Papp & Küpper (1953) most probably belongs to *G. falsostuarti* Sigal. Through the kindness of Dr. J. Sigal, the type specimens of *G. falsostuarti*, which are in his personal collection, were examined by the present author. This examination showed that :

1. The holotype of *G. falsostuarti* is distinguished by its unequally biconvex test ; strongly protruding ventral side ; two closely spaced keels, the ventral one of which is slightly shifted towards the inner side of the test and is reduced

on the last chamber ; its highly beaded keels and dorsal sutures ; inclined peripheral band ; raised, beaded, discontinuous umbilical flange ; and inclined, raised, beaded ventral sutures. It is more closely related to *G. arca* (Cushman) than to *G. stuarti stuarti* (de Lapparent).

2. The paratypes of *G. falsostuarti* include forms belonging to *G. stuarti stuarti* (de Lapparent), *G. conica* White, *G. esnehensis* Nakkady & Osman and *G. fareedi* sp. nov.

The similarity in the shape of the chambers and the sutures on both sides, the distinctly lobate, circular periphery and the entirely single keel, suggest that *G. fareedi* sp. nov. has possibly evolved from *G. elevata* (Brotzen) in early Maestrichtian time, although its evolution from *G. stuarti stuarti* (de Lapparent) is not excluded. Again, *G. fareedi* may have evolved into *G. esnehensis* Nakkady & Osman in early Middle Maestrichtian time by increasing the convexity of the dorsal side and flattening the ventral side. The diagnostic features and stratigraphical ranges of these species favour these propositions.

This species is named after Dr. Fareed El-Naggar of the National Institute of Management Development, Cairo.

HOLOTYPE. P.45528.

PARATYPES. P.45666.

HORIZON AND LOCALITY. Holo- and paratypes, from Sample No. 24, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. *G. fareedi* occurs as rare to common in the L. Maestrichtian *G. fornicata* Zone, common to abundant in the Middle Maestrichtian *G. gansseri* Zone, and dies out in the basal part of the Upper Maestrichtian *G. esnehensis* Zone.

Globotruncana fornicata ackermanni Gandolfi

(Pl. 14, figs. 3*a*–5*d*)

1955 *Globotruncana fornicata ackermanni* Gandolfi : 42–43, pl. 2, figs. 5*a*–7*c*.
? 1958 *Globotruncana fornicata ackermanni* Gandolfi ; Ansary & Fakhr : 135, pl. 2, figs. 16*a*–*c*.

DESCRIPTION. (Specimen, Pl. 14, figs. 4*a*–*d*.) Test small, biconvex, coiled in a low trochospire ; dorsal side slightly convex, moderately inflated, ventral side inflated, moderately protruding ; equatorial periphery roughly ovoid or rather quadrate, moderately lobate, with two well-developed, delicately beaded, slightly diverging, imbricate keels, enclosing a wide, slightly depressed peripheral band ; axial periphery globular, subtruncate ; chambers on the dorsal side 15, arranged in 3 dextrally coiled whorls ; the initial ones are small, globular, inflated, increase slowly in size and are followed by relatively larger, globular, more inflated chambers which increase moderately in size ; the last whorl is composed of 4 large chambers which are subglobular in the early part, crescentic and strongly elongated in the direction of coiling in the later part and which increase rapidly in size ; the last chamber is very well-developed and constitutes about $\frac{1}{3}$ of the test ; on the ventral side the chambers are 4, large, subglobular in the early part, ovoid in the last chamber, strongly inflated and increase rapidly in size ; sutures on the dorsal side curved, raised, delicately beaded and merge into relatively shallow depressions from the periphery inwards towards the spiral suture ; on the ventral side the sutures are radial and depressed ; umbilicus irregular in outline, wide, deep and covered by complex tegilla of which remnants are still preserved ; primary apertures interio-marginal, umbilical ; tegilla, with accessory apertures, only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface rough, coarsely papillose.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·38 mm.
Minimum diameter = 0·29 mm.
Thickness = 0·22 mm.

VARIATION. The main variation observed in *G. fornicata ackermanni* is in the degree of inflation of both sides, imbricate arrangement of keels, rate of growth and surface rugosity.

REMARKS. *Globotruncaca fornicata ackermanni* is believed to have evolved from *G. fornicata fornicata* Plummer by reduction in the size of test, greater inflation of the chambers, imbricate arrangement of keels and peripheral band and the development of surface rugosity. The form here figured (Pl. 14, figs. 3*a–d*) shows intermediate characters between the two subspecies and is thus considered as a transitional stage.

HYPOTYPES. P.45529.

HORIZON AND LOCALITY. Figured specimes, from sample No. 4, Abou Saboun section.

STRATIGRAPHICAL RANGE : Gandolfi (1955) described *G. fornicata ackermanni* from the Colon shale of northeastern Colombia, where he considered its range as Campanian–Lower Maestrichtian. It was also recorded from the Maestrichtian of Um El-Huetat section west of Safaga, Eastern Desert, Egypt (Ansary & Fakhr, 1958).

In the Esna–Idfu region, *G. fornicata ackermanni* occurs as a common to abundant form in the Lower Maestrichtian *G. fornicata* Zone and dies out completely towards the top part of this zone.

Globotruncana fornicata cesarensis Gandolfi

(Pl. 13, figs. 3*a*–4*c* ; Pl. 14, figs. 6*a–c*)

1955 *Globotruncana fornicata cesarensis* Gandolfi : 45, pl. 2, figs. 10*a–c*.

DESCRIPTION. (Specimen, Pl. 14, figs. 6*a–c*.) Test medium-sized, biconvex, coiled in a low trochospire ; dorsal side convex, moderately inflated, and slightly folded in the last chamber, ventral side slightly inflated ; equatorial periphery roughly ovoid, moderately lobate, with two well-developed, delicately beaded marginal keels enclosing a wide peripheral band which widens out towards the last chamber ; axial periphery truncate ; chambers on the dorsal side are not all clear but appear to be 15 in number, arranged in 3 dextrally coiled whorls ; initial chambers extremely small, globular, weakly inflated and increase slowly in size ; they are followed by slightly larger, globular inflated chambers which increase slowly in size up to the beginning of the last whorl where they start to enlarge very rapidly ; the last whorl is composed of 4 large, strongly inflated chambers which are roughly globular in the early part, crescentic and strongly elongated in the direction of coiling in the later part and increasing so rapidly in size that the last chamber constitutes about half the test ; on the ventral side the chambers are 4, subglobular in the early part, strongly elongated in the last chamber which constitutes about half of the test ; sutures on the dorsal side curved, raised, beaded, merging into relatively sharp depressions before joining the spiral suture ; on the ventral side the sutures are radial and depressed ; umbilicus irregular in outline, relatively wide, deep, bordered by weakly raised, delicately beaded umbilical ridges, and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal umbilical ; tegilla, with accessory apertures, only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface rough, delicately papillose, with the roughness decreasing gradually towards the last chamber.

Dimensions of described specimen.

Maximum diameter = 0·43 mm.
Minimum diameter = 0·31 mm.
Thickness = 0·25 mm.

Variation. The main variation observed in this subspecies is in the degree of inflation of the chambers in the last whorl, the degree of surface plication on the dorsal side and in the surface roughness.

Remarks. *Globotruncana fornicata cesarensis* was first described by Gandolfi (1955) and considered to represent a final stage in the evolution of the *G. fornicata* group, characterized by the reduction in the size of test and in the number of chambers in the last whorl. The present study substantiates Gandolfi's conclusion, although his *G. fornicata plummerae* which he regarded as the ancestor of *G. fornicata cesarensis*, is here considered a junior synonym of *G. fornicata fornicata* Plummer.

Specimens of *G. fornicata cesarensis*, from the Esna–Idfu region, conform well with Gandolfi's original description and figures. However, two distinct morphological types of this subspecies were recorded, one with a smooth test and a non-inflated dorsal side (e.g. Pl. 13, figs. 3*a–c*), the other with a moderately to distinctly inflated dorsal side and a rougher surface. The former type was clearly observed high in the section while the latter was found to flood the lower part. It is possible that further study may prove these types to be worthy of distinction. However, as such variation was mentioned by Gandolfi (1955), and as the former type was found to be rather rare in the samples studied, the two forms are here assigned to the same subspecies.

Hypotypes. P.45530.

Horizon and locality. Figured specimens, Pl. 13, figs 3*a–c* from sample No. 16, W. El-Sharawna section, figs. 4*a–c*, from sample No. 14, Gebel △ 314 section ; Pl. 14, figs. 6*a–c*, from sample No. 4, Abou Saboun section.

Stratigraphical range. Gandolfi (1955) described this subspecies from the Colon shale of northeastern Colombia where he considered its range as Campanian–basal Maestrichtian.

In the Esna–Idfu region, *G. fornicata cesarensis* floods the Lower Maestrichtian *G. fornicata* Zone, fades out gradually upwards in the section and occurs as a rare form in the basal part of the overlying *G. gansseri* Zone where it dies out completely.

Globotruncana fornicata fornicata Plummer

(Pl. 13, figs. 5*a–c*, 6 ; Pl. 14, figs. 1*a–c*)

1931 *Globotruncana fornicata* Plummer : 198, pl. 13, figs. 4*a–c*, 5, 6.
1951 *Globotruncana fornicata* Plummer ; Drooger : 7, pl. 1, figs. 9*a–c*.
1953 *Globotruncana fornicata* Plummer ; Hagn : 98, pl. 8, figs. 8*a–c*, text-figs. 22, 23.
1953 *Globotruncana fornicata* Plummer ; Subbotina : 184–185, pl. 8, figs. 3*a–c*, ? 4*a*–5*c*.
1955 *Globotruncana* (*Globotruncana*) *fornicata plummerae* Gandolfi : 42, pl. 2, figs. 3*a–c*, ? 4*a–c*.
1961 *Globotruncana fornicata* Plummer ; Graham & Clark : 112, pl. 5, figs. 10*a—c*.
1962 *Globotruncana* (*Globotruncana*) *fornicata* Plummer ; Pessagno : 362, pl. 4, figs. 4, 5, 11.
1963 *Globotruncana fornicata* Plummer ; Lehmann : 148, pl. 7, figs. 1*a*–2*c* ; ? 3*a*–4*c* ; text-figs. 2*v*, *w* ; 3*n*, *r*, *t*

Description. (Specimen, Pl. 13, figs. 5*a–c*.) Test large, biconvex, coiled in a low trochospire ; dorsal side slightly convex, moderately inflated, ventral side slightly more inflated and relatively protruding ; equatorial periphery ovoid, slightly lobate, with two well-developed, delicately beaded diverging keels ; axial periphery truncate ; chambers on the dorsal side 17, arranged in 3 dextrally coiled whorls ; initial chambers very small, almost indistinct, globigerine, weakly inflated, increasing slowly in size ; they are followed by relatively larger, globular, slightly inflated chambers which also increase slowly in size till the beginning of the last whorl where they start to change their shape and rate of growth ; the last whorl constitutes most of the test and is composed of 4¼ large, long, narrow inflated, slightly folded, highly curved crescentic chambers ; on the ventral side the chambers are 4, kidney-shaped, moderately inflated and strongly overlapping ; sutures on the dorsal side are curved, raised, delicately beaded, tending to merge into relatively sharp depressions from the periphery inwards towards the preceding whorl (as in Plummer's description) ; on the ventral side the sutures are strongly curved forward, slightly raised and delicately beaded ; umbilicus roughly rhomboidal in outline, wide, deep, bordered by slightly raised delicately beaded ridges, covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla, with accessory apertures, only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface delicately papillose in the early part and on the ventral side, becoming smooth towards the last chamber ; the two keels enclose a relatively wide, depressed, slightly inclined peripheral band which is relatively narrow at the posterior part of test but widens out anteriorly as the keels diverge.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·51 mm.
Minimum diameter = 0·39 mm.
Thickness = 0·24 mm.

MAIN VARIATION.

1. Test medium-sized to large, subcircular to ovoid in outline.
2. Dorsal side very slightly raised to moderately convex, gently plicate to slightly folded.
3. Ventral side inflated, slightly to moderately protruding.
4. Chambers 14–18, arranged in 2½–3 whorls, usually dextrally coiled (of 60 specimens picked at random, 4 coiled sinistrally).
5. Usually 4 or 5 chambers in the last whorl : specimens with 3½ or 6 chambers occur very rarely.
6. The peripheral band varies in width and in degree of inclination towards the ventral side.
7. The two keels can either be occasionally developed or the ventral keel may equally weaken towards the last chamber.
8. The surface is generally smooth but is sometimes delicately papillose in the early part.

REMARKS. As was mentioned in part by Gandolfi (1955) *Globotruncana fornicata* Plummer (1931) and of authors, is actually a group of closely related forms. These are generally characterized by a biconvex, double-keeled test, small, globigerine, early chambers, and long, narrow highly arched later ones ; these are slightly to moderately plicate on the dorsal side and moderately to strongly overlapping on the ventral. They are also characterized by a slightly inclined peripheral band and dorsal sutures which merge into relatively sharp depressions from the periphery inwards.

Gandolfi considered some of these related forms to be subspecies of *G. fornicata*, and described the following :

Globotruncana fornicata fornicata Plummer 1931.
Globotruncana fornicata plummerae Gandolfi 1955.
Globotruncana fornicata ackermanni Gandolfi 1955.
Globotruncana fornicata cesarensis Gandolfi 1955.
Globotruncana fornicata manaurensis Gandolfi 1955.

However, Gandolfi's specimen described as *G. fornicata fornicata* Plummer differs from Plummer's original description and figures and may possibly be a distinct form. On the other hand, examination of topotypes of *G. fornicata plummerae*, kindly presented by Dr. R. Gandolfi, proved their identity with *G. fornicata fornicata* Plummer from the Esna–Idfu region and with topotype material kindly sent by Dr. E. A. Pessagno, Jr., of the University of California. Thus *G. fornicata plummerae* Gandolfi is considered to be a junior synonym of *G. fornicata fornicata* Plummer.

The other forms described by Gandolfi are here recognized as valid subspecies. A new subspecies of *G. fornicata* was also discovered during the present study and named *G. fornicata globulocamerata* ; it is distinguished by a tendency to have globular chambers in the last whorl instead of the extremely elongated chambers of the central type.

The lumping of these subspecies and their transitional forms as *G. fornicata* Plummer has confused the diagnostic features and stratigraphical range of *G. fornicata fornicata.* However, it is clearly distinguished by its biconvex test, extremely elongated chambers in the last whorl which are slightly plicate on the dorsal side and sometimes inflated towards their inner extremities, and strongly overlapping on the ventral side ; its curved, raised, beaded, ventral sutures and strongly diverging double keel.

Glaessner (1937 : 43, text-fig. 5) suggested the evolution of *G. fornicata* Plummer from *Rotalipora appenninica* (Renz), in Coniacian–Santonian time through a yet unknown form. However, Bolli (1951) and Gandolfi (1955, pl. 10) suggested its evolution from *G. lapparenti lapparenti* (Brotzen) while Brönnimann & Brown (1956) suggested that it evolved from *G. imbricata* Mornod. Moreover, Gandolfi (1955) suggested the evolution of *G. fornicata fornicata* Plummer from *G. fornicata manaurensis* by the gradual reduction of the tight coiling of the chambers, by the reduction in the number and degree of overlap of chambers, and by the anterior divergence of the two keels. It is also evident that members of the *G. fornicata* group have gradually evolved into the corresponding members of the *G. contusa* group, through various transitional stages, as was partly mentioned by Glaessner (1937), Bolli (1951), Gandolfi (1955), and Brönnimann & Brown (1956), and is clearly documented in the present study.

G. fornicata fornicata is believed to have evolved into *G. contusa contusa* through *G. contusa witwickae* subsp. nov., and into *G. contusa* sensu Troelsen through *G. fornicata globulocamerata* subsp. nov.

HYPOTYPES. P.45531.

HORIZON AND LOCALITY. Figured specimens, Pl. 13, figs. 5*a–c*, from sample No. 14, G. △ 314 ; fig. 6, from sample No. 3, Abou Saboun section ; Pl. 14, figs. 1*a–c* from sample No. 4 Abou Saboun section.

STRATIGRAPHICAL RANGE. *Globotruncana fornicata fornicata* Plummer was first described from the Upper Taylor (Campanian) Formation of Texas (Plummer 1931, sta. 226–T–8) and was recorded as very common to abundant in Taylor and Navarro strata which, according to Bolli (1957, 1959), corresponds to the Upper Santonian–Lower Maestrichtian of Western Europe. It was recorded from the same horizon by Cushman & Todd (1943), Cushman (1944, 1946, 1948), and by Frizzell (1954) who showed that it ranges throughout the whole Taylor and Lower Navarro groups, being most abundant in the upper Taylor beds, and that it never occurs below the base of the Taylor formation. Albritton & Phleger (1937) restricted its range to the Taylor group only, while Brönnimann & Brown (1956) recorded its range as Coniacian to Campanian, possibly Maestrichtian. Hagn (1953) described it from the Upper Campanian of Germany, Barr (1962) from the Campanian of the Isle of Wight.

England, and Lehmann (1963) from the Coniacian–Campanian of the Tarfaya province, western Morocco.

Other authors, by misidentifying Plummer's species, or by confusing it with other subspecies, gave various ranges between Upper Turonian and Lower Maestrichtian, although it was clearly stated (Frizzell 1954) that in the type locality it was not found below the Upper Santonian (base of the Taylor formation).

In the Esna–Idfu region *Globotruncana fornicata fornicata* Plummer floods the basal part of the Sharawna shale formation, characterizing the *G. fornicata* Zone, to which it is restricted and in which it constitutes, together with its subspecies, the bulk of the planktonic Foraminifera. It fades out gradually upwards in the section disappearing completely below the overlying *G. gansseri* Zone.

Globotruncana fornicata globulocamerata subsp. nov.

(Pl. 13, figs. 1*a–c* ; Pl. 14, figs. 2*a–c*)

Diagnosis. A *Globotruncana fornicata* with globigerine character of early chambers extending to most of last whorl, final one or two chambers only are distinctly elongated in direction of coiling.

Description. (Holotype, Pl. 14, figs. 2*a–c*.) Test medium sized, biconvex, coiled in a low trochospire ; dorsal side gently arched and moderately inflated, ventral side slightly inflated and weakly protruding ; equatorial periphery roughly ovoid, weakly lobate, with two well-developed, much thickened and delicately beaded marginal keels enclosing a relatively wide, slightly inclined peripheral band, which widens out gradually towards the last chamber ; axial periphery distinctly truncate ; chambers on the dorsal side 17, arranged in 3 dextrally coiled whorls ; the initial chambers are exceedingly small, almost indistinct, slightly depressed, globular, weakly inflated, and increase very slowly in size ; they are followed by relatively larger, globular, inflated chambers which increase moderately in size ; the last whorl is composed of 5 large, inflated chambers which are subglobular and increase slowly in size except for the last which is crescentic, strongly elongated in the direction of coiling, and constitutes about $\frac{1}{3}$ of the test ; on the ventral side the chambers are 5, large, inflated, subglobular, moderately overlapping and increase slowly is size except the last one which is ovoid, elongated, strongly inflated and constitutes about $\frac{1}{3}$ of the test ; sutures on the dorsal side slightly curved, raised and delicately beaded, although the inflation of the chambers on both sides makes them appear to run in very shallow sutural depressions ; on the ventral side the sutures are curved, slightly raised and delicately beaded ; umbilicus irregular in outline, relatively wide, shallow, bordered by slightly raised, delicately beaded ridges and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla, with accessory apertures, only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface slightly rough, delicately papillose especially on the ventral side with the roughness decreasing gradually towards the last chamber.

Dimensions of holotype.

Maximum diameter = 0·43 mm.
Minimum diameter = 0·32 mm.
Thickness = 0·22 mm.

Variation. The main variation observed in specimens of *G. fornicata globulocamerata* is in the degree of globularity of the last chambers and the degree of surface roughness.

Remarks. All members of the *G. fornicata* group are generally characterized by an early globigerine part, and later crescentic chambers which are strongly curved and distinctly elongated in the direction of coiling. The present form, however, represents a distinct type of this group in which the early globigerine character extends to most of the final whorl, while the last one or two chambers still keep the characteristic chamber form which is strongly elongated in the direction of coiling. As all the other characters of the *G. fornicata* group are retained in the present form, and as it has a slightly different stratigraphical range from *G. fornicata fornicata* Plummer, it is here considered as a distinct subspecies. The name *G. fornicata globulocamerata* describes the globular character of most of its chambers.

G. fornicata globulocamerata is believed to have evolved from *G. fornicata fornicata* Plummer, and into *G. contusa* sensu Troelsen, as suggested by the morphology and stratigraphical distribution of these forms.

Holotype. P.45532.

Paratypes. P.45533–34.

Horizon and locality. Holotype, Pl. 14, figs. 2*a–c*, and paratype Pl. 13, figs. 1*a–c*, from samples No. 4 and 3 respectively, Abou Saboun.

Stratigraphical range. In the Esna–Idfu region, *G. fornicata globulocamerata* occurs as a common to abundant form throughout the Lower Maestrichtian *G. fornicata* Zone, fading out gradually upwards in the section and dying out completely below the overlying *G. gansseri* Zone.

Globotruncana fornicata manaurensis Gandolfi

(Pl. 13, figs. 2*a–c*)

1955 *Globotruncana fornicata manaurensis* Gandolfi : 41, pl. 2, fig. 1*a–c*, text-fig. 9 (1*a–c* ; 2*a–c*).

Description. Test medium-sized, unequally biconvex, coiled in a low trochospire ; dorsal side convex, moderately arched and slightly inflated, ventral side almost flat, slightly raised and weakly inflated ; equatorial periphery subcircular, slightly lobate, with two well-developed, closely spaced, thickened marginal keels ; axial periphery subangular, subtruncate ; chambers on the dorsal side are not all clear, but appear to be 18 in number, arranged in 3 dextrally coiled whorls ; the initial chambers are very small, almost indistinct and are followed by slightly larger, globular, inflated chambers which become roughly crescentic towards the last whorl and increase moderately in size ; the last whorl is composed of 6 (5 + 1 abortive) large chambers which are highly arched, distinctly elongated in the direction of coiling and increase slowly in size ; on the ventral side the chambers are 5, large, ovoid, and distinctly overlapping while they increase slowly in size ; each chamber is surrounded by a horseshoe-shaped, delicately beaded raised ridge ; sutures on the dorsal side strongly curved, distinctly raised, much thickened and limbate ; on the ventral side the sutures are strongly curved forward, slightly raised and limbate; umbilicus roughly pentagonal in outline, wide, deep, surrounded by much-thickened ridges and covered by complex tegilla, of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla, with accessory apertures, only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface smooth.

Dimensions of described specimen.

Maximum diameter = 0·41 mm.
Minimum diameter = 0·35 mm.
Thickness = 0·22 mm.

Remarks. Gandolfi (1955) considered this subspecies to be the ancestral stock from which both the *G. fornicata* and the *G. contusa* groups have evolved, through *G. fornicata fornicata* Plummer in the former, and *G. contusa scutilla* Gandolfi in the latter. He also mentioned a somewhat dubious relationship with what he described as the *G. caliciformis–intermedia* group and suggested the evolution of the present subspecies from *G. lapparenti lapparenti* (Brotzen) [= *G. linneiana linneiana* (d'Orbigny)].

The present study substantiates Gandolfi's suggestion in part, namely that *G. fornicata manaurensis* evolved from *G. linneiana linneiana* (d'Orbigny) and that it possibly evolved into *G. fornicata fornicata* Plummer. Transitional stages between the present subspecies and *G. tricarinata tricarinata* (Quereau), were also recorded (e.g. Pl. 14, figs. 7*a–c*).

Specimens of *G. fornicata manaurensis*, although rare in the samples studied, compare well with Gandolfi's original description and figures, and with topotype material kindly forwarded to the present author by Dr. R. Gandolfi.

Hypotypes. P.45535–36.

Horizon and locality. Figured specimen from Sample No. 14, G. △ 314 section.

Stratigraphical range. *Globotruncana fornicata manaurensis* was described by Gandolfi (1955) from the Manaure shale of northeastern Colombia where he considered its range as Coniacian–Santonian. In the Esna–Idfu region it occurs as a very rare form in the Lower Maestrichtian *G. fornicata* Zone only.

Globotruncana fundiconulosa Subbotina

1953 *Globotruncana fundiconulosa* Subbotina : 200, 201, pl. 14, figs. 1*a*–4*c* ; pl. 15, figs. 1*a*–2*b*.
1955 *Globotruncana wiedenmayeri wiedenmayeri* Gandolfi : 71, pl. 7, figs. 4*a–c*.
? 1955 *Globotruncana wiedenmayeri magdalenaensis* Gandolfi : 72, pl. 7, figs. 3*a–c*.

REMARKS. The forms described by Gandolfi (1955) as *G. wiedenmayeri wiedenmayeri* and *G. wiedenmayeri magdalenaensis* are morphologically similar to the present species, and have the same stratigraphical range. They are thus considered to be junior synonyms, as previously mentioned by Berggren (1962).

HYPOTYPE. P.45537.

HORIZON AND LOCALITY. Hypotype from sample No. 18, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. The species was recorded by Subbotina (1953) to range through the Campanian–Maestrichtian of the U.S.S.R., and by Gandolfi (1955) from the Campanian–Maestrichtian of northeastern Colombia. In the Esna–Idfu region *G. fundiconulosa* occurs as a rare form in the Lower Maestrichtian *G. fornicata* Zone and the lower part of the overlying *G. gansseri* Zone where it dies out completely.

Globotruncana gagnebini Tilev

(Pl. 2, figs. 1*a*–4*d* ; Pl. 3, figs. 1*a*–*d*, 3*a*–*d*, 6)

1951 *Globotruncana gagnebini* Tilev : 50–56, pl. 3, figs. 2–5, text-figs. 14*a*–*e*, 15*a*–17*d*.
1951 *Globotruncana ventricosa* White ; Bolli : 190, text-fig. 1*e*.
1951*a* *Globotruncana cretacea* Cushman ; Nakkady (pars) : 57–58, pl. 2, fig. 2D, E, non A–C.
1952 *Globotruncana gagnebini* Tilev ; Tilev : 50–56, pl. 3, figs. 2–5, text-figs. 14*a*–*e*, 15*a*–17*d*.
1955 *Globotruncana ventricosa ventricosa* (White) ; Gandolfi : 22, 23 ; pl. 1, figs. 5*a*–*c*.
1955 *Globotruncana arca caribica* Gandolfi : 64, pl. 5, figs. 5*a*–*c*.
1957*a* *Globotruncana gagnebini* Tilev ; Bolli : 59, pl. 14, figs. 5*a*–*c*.

DESCRIPTION. (Specimen, Pl. 2, figs. 1*a*–*d*.) Test large, planoconvex, umbilico-convex, coiled in a very low trochospire ; dorsal side almost flat, ventral side distinctly protruding ; equatorial periphery roughly ovoid, slightly lobate, with two well-developed, thickened, beaded keels enclosing a narrow peripheral band ; axial periphery truncate ; chambers on the dorsal side 14, arranged in 3 dextrally coiled whorls ; the initial ones are small, inflated, globigerine, and increase slowly in size ; the last whorl is composed of 5¼, large, crescentic chambers which are elongated in the direction of coiling and increase very rapidly in size ; on the ventral side the chambers are 5¼, large, raised, distinctly protruding, subglobular in the early part and elongate later ; sutures on the dorsal side curved, raised and beaded ; on the ventral side they are radial or very slightly curved forward and depressed ; umbilicus wide, deep, bordered by raised, thick, limbate ridges and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface smooth except for a few scattered papillae on the early part.

DIMENSIONS OF DESCRIBED SPECIMEN.
Maximum diameter = 0·42 mm.
Minimum diameter = 0·35 mm.
Thickness = 0·22 mm.

MAIN VARIATION.

1. The test is small to large, subcircular to ovoid, moderately to strongly elongate.
2. The dorsal side is either flat, very slightly raised or even slightly depressed, while the ventral side is always protruding, sometimes strongly so that the protruding ventral mass lies almost at right angles to the marginal periphery.
3. Equatorial periphery subcircular to ovoid, slightly to moderately lobate ; axial periphery moderately to distinctly truncate.
4. The two marginal keels are either equally developed or the ventral keel is sometimes reduced on the last chamber (e.g. Pl. 2, fig. *2b*).
5. The keels, sutures and umbilical flange can either be heavily beaded throughout or beaded in the early part, thickened and limbate in the later part.
6. Chambers on the dorsal side 14–16, arranged in 3 whorls, generally dextrally coiled (all studied specimens coiled dextrally).
7. Chambers in the last whorl 4–6, most commonly 5, large, moderately or strongly elongated in the direction of coiling, increasing very rapidly in size.
8. The last chamber is either well-developed and constitutes $\frac{1}{4}$–$\frac{1}{3}$ of the test (e.g. Pl. 2, fig. 1 ; Pl. 3, fig. 3), or is sometimes reduced in size, becoming much smaller than the penultimate (Pl. 2, fig. 2).
9. The umbilicus varies in shape, but is always wide, deep, and surrounded by a raised umbilical flange which is either heavily beaded or just thickened and limbate.
10. The surface is generally smooth but is sometimes covered by large scattered papillae especially on the ventral side.

REMARKS. *Globotruncana gagnebini* was first described by Tilev (1951) who mentioned that it morphologically resembles *G. pendens* Vogler, *G. ventricosa* White and *G. lugeoni* Tilev, but is quite distinct.

Bolli (1951) and Gandolfi (1955) described as *G. ventricosa* White, and *G. ventricosa ventricosa* (White) respectively, forms which are actually *G. gagnebini* Tilev, as in part reconsidered by Bolli (1957*a*). Gandolfi also described as *G. arca caribica*, a form which appears to be transitional between *G. gagnebini* Tilev and *G. aegyptiaca aegyptiaca* Nakkady, and is here considered to be a junior synonym of the former. Gandolfi's form closely resembles the specimen here figured, Pl. 3, figs. 1*a–d*.

Berggren (1962) considered *G. gagnebini* Tilev to be a junior synonym of *G. aegyptiaca aegyptiaca* Nakkady, but the present study showed clearly that the morphological features of the two species strongly warrant their separation in spite of their apparent similarity. *G. gagnebini* is distinguished from *G. aegyptiaca aegyptiaca* by its elongate, tightly coiled, ovoid test ; its greater number of chambers in the last whorl which increase very rapidly in size ; its weakly lobate periphery, more closely spaced keels and less rough surface.

Globotruncana gagnebini is believed to have evolved from *G. ventricosa* White by reduction in the size of test and in the number of chambers in the last whorl, by more rapid increase in the size of the chambers, and by the development of an elongate test as well as a slightly rougher surface. The morphological characters and stratigraphical distribution of the two species are strongly in favour of this proposition which is substantiated by the occurrence of several transitional stages (see Pl. 2, figs. 3*a–d*).

On the other hand, forms which can be morphologically considered as transitional between *G. gagnebini* and *G. aegyptiaca aegyptiaca* were recorded, and may suggest the evolution of the former into the latter. But the fact that the two species have always been confused with each other does not allow one to distinguish precisely their respective stratigraphical ranges which are generally considered to be the same. However, the apparent morphological similarity of the two species may be due to " parallel evolution " from two distinct but genetically related forms.

HYPOTYPES. P.45538.

HORIZON AND LOCALITY. Figured specimens, Pl.2, figs. 1*a–d*, 2*a–d* ; Pl. 3, fig. 6, from sample No. 16, W. El-Sharawna section ; Pl. 2, figs. 3*a–d*, which is a transitional stage to *G. ventricosa* White, and Pl. 3, figs. 3*a–d*, from sample No. 18, W. El-Sharawna section ; Pl. 2, figs. 4*a–d*, from sample No. 4, Abou Saboun section ; Pl. 3, figs. 1*a–d*, from sample No. 11, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globotruncana gagnebini* was first described by Tilev (1951) from the Maestrichtian of southeastern Turkey where it was recorded to range throughout the stage. It was also recorded from the Maestrichtian of Trinidad (Bolli 1951, 1957*a*) as ranging throughout the *G. gansseri* and the *Abathomphalus mayaroensis* Zones.

In the Esna–Idfu region, *G. gagnebini* Tilev floods the Maestrichtian part of the studied sections ; it is abundant in the *G. fornicata* Zone, floods the *G. gansseri* Zone and is rare in the *G. esnehensis* Zone, where it dies out completely.

***Globotruncana* cf. *gagnebini* Tilev**

(Pl. 3, figs. 2*a–d*)

REMARKS. The tendency of *G. gagnebini* Tilev to have a slightly raised dorsal side was mentioned by Tilev (1951) and was observed in the present study. However, none of Tilev's figures nor the typical specimens here studied, was found to have a conical dorsal side. The form here described as *G.* cf. *gagnebini* is closely related to Tilev's form, but differs only in having a gently coned, dorsal side. Morphologically, this form should be considered separately, but because it was found to be rather rare in the samples studied, it is provisionally described as *G.* cf. *gagnebini*.

HYPOTYPE. P.45539.

HORIZON AND LOCALITY. Figured specimens from sample No. 4, Abou Saboun section.

STRATIGRAPHICAL RANGE. *Globotruncana* cf. *gagnebini* is rare in the Lower Maestrichtian *G. fornicata* Zone and in the basal part of the Middle Maestrichtian *G. gansseri* Zone of the Esna–Idfu region.

Globotruncana gansseri dicarinata Pessagno

(Pl. 5, figs. 4*a–d*)

1960 *Globotruncana* (*Rugotruncana*) *gansseri dicarinata* Pessagno : 103, pl. 2, figs. 9–11 ; pl. 3, figs. 1–3 ; pl. 5, fig. 2.

DESCRIPTION. Test large, planoconvex, umbilico-convex, coiled in a very low trochospire ; dorsal side flat, ventral side strongly protruding, equatorial periphery roughly ovoid or rather quadrate, distinctly lobate, with two well-developed, thickened, heavily beaded, widely spaced keels, reduced to a single keel on the last chamber ; axial periphery truncate in the early part, subangular in the later ; chambers on the dorsal side are not all clear because of the surface rugosity, but appear to be 16 in number, arranged in 3 dextrally coiled whorls ; the initial chambers are extremely small, indistinct, almost masked by the surface rugosity, increase very slowly in size and are followed by globular to crescentic, weakly inflated chambers which also increase slowly in size ; the last whorl is composed of 5 large, crescentic chambers which increase rapidly in size ; on the ventral side the chambers are 5 large, angular conical and strongly protruding ; sutures on the dorsal side curved, raised and heavily beaded ; on the ventral side they are straight, radial and depressed ; umbilicus roughly pentagonal in outline, wide, deep, surrounded by a raised, beaded, umbilical flange in the early part, which fades out gradually towards the last chamber, and is covered by complex tegilla of which remnants are still preserved; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate except for the imperforate keels, peripheral band and tegilla ; surface rough, heavily papillose, nodose, or spinose in the early part with the rugosity decreasing gradually towards the last chamber.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·50 mm.
Minimum diameter = 0·35 mm.
Thickness = 0·26 mm.

REMARKS. Pessagno (1960) stated that this subspecies differs from *G. gansseri gansseri* Bolli in having a distinct double keel and well-developed rugosities in the early stages. He also added that it is intermediate between *Rugoglobigerina rugosa subrugosa* Gandolfi and *G. gansseri gansseri* Bolli and that it has evolved from the former by dorsal flattening and the migration of the double-keel band to the dorsal periphery. However, this subspecies appears to be more closely related to *G. gagnebini* Tilev from which it differs only by the well developed surface rugosity. Thus its assignment to *G. gansseri* may seem doubtful, as the last mentioned species is characterized by its entirely single keel. However, the fact that Brönnimann & Brown (1956) and Pessagno (1960) observed a double-keeled rugoglobigerine nepionic stage in thin sections of *G. gansseri gansseri*, may support Pessango's hypothesis that the latter subspecies has evolved from *G. gansseri dicarinata* by the gradual reduction of the ventral keel. The specimen here figured as *G. gansseri dicarinata* Pessagno conforms well with the holotype, while the paratype figured by Pessagno (1960) lacks the typically crescentic shape of the chambers on the dorsal side and the distinctly lobate periphery characteristic of the holotype. Examination of topotype specimens, kindly presented by Dr. E. A. Pessagno, Jr., showed clearly that they are more like the figures of the paratype of Pessagno than those of the holotype. The limited number of specimens found in the present study does not allow the evolutionary history of this subspecies to be followed although its evolution from *G. gagnebini* Tilev is not excluded, despite Pessagno's statements.

HYPOTYPE. P.45540.

HORIZON AND LOCALITY. Figured specimen, from sample No. 16, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globotruncana gansseri dicarinata* was first described by Pessagno (1960) from the Rio Yauco mudstone formation of Puerto Rico where it was stated to be common in the lower part of the Maestrichtian *G. tilevi* Subzone, and to constitute a particular faunal zonule, the *G. gansseri dicarinata* Zonule.

In the Esna–Idfu region, it occurs as a rare to common form in the Middle Maestrichtian *G. gansseri* Zone, and dies out completely in the basal part of the Upper Maestrichtian *G. esnehensis* Zone.

Globotruncana gansseri gandolfii subsp. nov.

(Pl. 5, figs. 2*a–d*)

1955 *Globotruncana gansseri gansseri* Bolli ; Gandolfi : 69–70, pl. 6, figs. 8*a–c*, text-fig. 11*b*.

DIAGNOSIS. A *Globotruncana* with small to large, quadrate, umbilico-convex test ; weakly inflated chambers on dorsal side, slightly imbricate in last whorl ; radial depressed ventral sutures, thin marginal keel slightly shifted towards dorsal side ; rough surface.

DESCRIPTION. Test large, roughly quadrate in outline, planoconvex, umbilico-convex, coiled in a very low trochospire ; dorsal side almost flat and somewhat imbricate although the chambers are weakly inflated and slightly overlapping; ventral side strongly inflated and distinctly protruding ; equatorial periphery roughly quadrate, moderately lobate, with a single, delicately beaded keel which is slightly shifted towards the dorsal side ; axial periphery subangular, subtruncate ; chambers on the dorsal side about 17 in number, arranged in 2½ dextrally coiled whorls ; the initial chambers are exceedingly small, globular, slightly inflated and almost masked by the surface rugosity ; they increase very slowly in size and are followed by relatively larger, subglobular, slightly inflated chambers which increase moderately in size ; the last whorl is composed of 4½, large, roughly ovoid chambers which increase moderately in size, although the last chamber is slightly smaller than the penultimate ; on the ventral side the chambers are 4½, large, subglobular, strongly inflated and distinctly protruding ; sutures on the dorsal side slightly curved, almost radial, raised and beaded, although the inflation of the chambers makes them appear to be slightly depressed in part, especially towards the inner whorl ; on the ventral side the sutures are straight, radial, and strongly incised umbilicus roughly quadrate in outline, relatively wide, deep, and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate except for the imperforate keel and tegilla ; surface on the dorsal side rough in the early part, covered with numerous small papillae which decrease gradually towards the last chamber ; on the ventral side the surface is very rough, heavily papillose or even nodose.

Dimensions of holotype.

Maximum diamter = 0·48 mm.
Minimum diameter = 0·33 mm.
Thickness = 0·28 mm.

Main variation.

1. Chambers 13–18, arranged in $2\frac{1}{2}$–3 whorls, generally dextrally coiled.
2. Chambers in the last whorl 4–5, flat to slightly inflated, slightly to moderately imbricate, increasing slowly in size except for the last, which is either slightly smaller or slightly larger than the penultimate.
3. The surface can either be rough throughout, heavily nodose or even spinose, or it can be delicately papillose in the early part and smooth later.

Remarks. Gandolfi (1955) described as *G. gansseri gansseri* Bolli from the Colon shale of northeastern Colombia, a form which differs from the holotype of Bolli (1951). Such a form is abundant in the samples studied; its morphological characters and stratigraphical range warrant its separation from the central type and therefore it is here considered as a new subspecies of *G. gansseri* Bolli. It is named *G. gansseri gandolfii*, after Dr. R. Gandolfi. It is believed to have evolved from either *G. gansseri gansseri* (Bolli) or *G. gansseri dicarinata* Pessagno, as suggested by the morphological features and stratigraphical ranges of these forms. On the other hand, *G. gansseri gandolfii* is morphologically related to *Globotruncana arabica* sp. nov. which appears slightly higher in the section and thus may possibly represent its direct descendant.

Holotype. P.45541.

Paratypes. P.45542.

Horizon and locality. Holo- and paratypes, from sample No. 21, W. El-Sharawna section, Esna–Idfu region.

Stratigraphical range. In the Esna–Idfu region *G. gansseri gandolfii* appears as a common to a flood form in the upper part of the Middle Maestrichtian *G. gansseri* Zone, and continues as a rare to a common form in the overlying *G. esnehensis* Zone where it dies out completely immediately below the disconformity separating this zone from the overlying basal Tertiary. All records of *G. gansseri gansseri* Bolli from rocks younger than the Middle Maestrichtian (e.g. Gandolfi 1955 and Berggren 1962) most probably refer to the present subspecies.

Globotruncana gansseri gansseri Bolli

(Pl. 5, figs. 1*a–d;* Pl. 11, fig. 3)

1951 *Globotruncana gansseri* Bolli : 196, 197 ; pl. 35, figs. 1–3.
1956 *Rugotruncana gansseri* (Bolli) Brönnimann & Brown : 549–550 ; pl. 23, figs. 7–9 ; text-fig. 23.
? 1960 *Globotruncana monmouthensis* Olsson : 50–51, pl. 10, figs. 22–24.
? 1960 *Globotruncana* (*Rugotruncata*) *gansseri*, Bolli; Pessagno : 102, pl. 4, fig. 11.

EMENDED DIAGNOSIS. A *Globotruncana* with large, planoconvex, umbilico-convex test, large chambers increasing very rapidly in size in last whorl ; chambers typically crescentic and strongly elongated in direction of coiling on dorsal side, and angular conical, distinctly protruding on ventral side ; entirely single keel in last whorl, curved, raised, beaded dorsal sutures and slightly curved, depressed ventral ones ; very large umbilicus and moderately to heavily papillose surface in early part of test.

DESCRIPTION. Test large, planoconvex, umbilico-convex, coiled in a very low trochospire ; dorsal side flat, ventral side strongly inflated and distinctly protruding ; equatorial periphery roughly ovoid, moderately lobate, with a single well-developed, beaded keel ; axial periphery truncate, angular acute ; chambers on the dorsal side 15, arranged in 2½, dextrally coiled whorls ; the initial chambers are small, globular, compressed ; they increase slowly in size and are followed by typically crescentic, much flattened chambers which increase rapidly in size ; the last whorl is composed of 5 large, crescentic, flattened chambers which are elongated in the direction of coiling and increase rapidly in size ; on the ventral side the chambers are 5, large, angular conical, strongly inflated and distinctly protruding ; sutures on the dorsal side curved, raised and beaded ; on the ventral side the sutures are very slightly curved to almost straight, radial and depressed ; umbilicus roughly pentagonal in outline, very wide, deep, bordered by raised, beaded ridges and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla, with accessory apertures, only poorly preserved ; wall calcareous, perforate, except for the imperforate keel and tegilla ; surface smooth on the dorsal side, coarsely papillose on the ventral, with the papillae becoming coarse and scattered towards the last chamber.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·62 mm.
Minimum diameter = 0·47 mm.
Thickness = 0·30 mm.

MAIN VARIATION.

1. Chambers 14–16, arranged in 2½–3 whorls, generally dextrally coiled (all studied specimens coiled dextrally).
2. Chambers in the last whorl 4½–5.

REMARKS. *Globotruncana gansseri* was first validly described by Bolli (1951) although he had previously (1950) used the name without giving any description or figure. Gandolfi (1955) described *G. gansseri subgansseri* as a new subspecies thus changing the name of Bolli's form to *G. gansseri gansseri*. However, the form figured by Gandolfi (1955) as *G. gansseri gansseri* Bolli was found to differ from the holotype of Bolli and is thus considered here separately.

Brönnimann & Brown (1956) introduced *Rugotruncana* as a new genus and included *G. gansseri* Bolli in it. However, as mentioned above, *Rugotruncana* Brönnimann & Brown 1956 is considered a junior synonym of *Globotruncana* Cushman 1927. These authors (1956) showed by thin sections of *G. gansseri gansseri* that the early part of the test has two well-developed marginal keels in spite of the entirely single-keeled last whorl. Pessagno (1960) also observed a double-keeled, rugoglobigerine nepionic stage in thin sections of *G. gansseri gansseri*, but added that some individuals may lack this initial double keel.

Olsson (1960) described as *G. monmouthensis*, a form which most probably belongs to the present subspecies.

Globotruncana gansseri Bolli (1951) was found to include the following four distinct subspecies:

Globotruncana gansseri gansseri Bolli 1951.
Globotruncana gansseri subgansseri Gandolfi 1955.
Globotruncana gansseri dicarinata Pessagno 1960.
Globotruncana gansseri gandolfii subsp. nov.

However, because of its entirely double keel, *G. gansseri dicarinata* appears to be morphologically distinct, despite the fact that thin sections of *G. gansseri gansseri* showed a double-keeled nepionic stage. Further study may prove that it should be treated separately although it has some features in common with the *G. gansseri* group.

Gandolfi (1955) suggested the evolution of *G. gansseri gansseri* Bolli from *G. rosetta pettersi* Gandolfi which was said to appear in older strata and to die out completely before the first appearance of *G. gansseri gansseri*. However, Pessagno (1960) suggested the evolution of *G. gansseri gansseri* from *G. gansseri dicarinata*, while the present study favours its evolution from *G. rosetta rosetta* (Carsey). On the other hand, *G. gansseri gansseri* might possibly have evolved in two directions, one leading to *G. gansseri subgansseri* and the other to *G. gansseri gandolfii*.

HYPOTYPE. P.45543.

HORIZON AND LOCALITY. Figured specimen, from Sample No. 18, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. *Globotruncana gansseri gansseri* was first described by Bolli (1951) from the Maestrichtian Lantern marl, Guayaguayare formation of Trinidad and all subsequent references restricted its range to the Maestrichtian.

In the Esna–Idfu region, *G. gansseri gansseri* appears in the basal part of the *Pecten* (*Chlamys*) *mayereymari* marl (*Pecten farafraensis* marl) ; it floods this rock unit and the basal part of the overlying shale member, characterizing a particular faunal zone, the *G. gansseri* Zone. It continues in the Upper Sharawna shale, fading out gradually upwards in the section and dies out completely in the basal part of the overlying *G. esnehensis* Zone.

Bolli (1957*a*) recognized the *G. gansseri* Zone in the Maestrichtian of Trinidad, where he considered it to start slightly above the base of the Maestrichtian. However, Brönnimann & Brown (1956) considered the range of this species to be Lower to Middle Maestrichtian, while the *G. gansseri* Zone is here considered to represent the Middle Maestrichtian only.

Globotruncana gansseri subgansseri Gandolfi

(Pl. 5, figs. 3*a–d*)

1955 *Globotruncana gansseri subgansseri* Gandolfi : 70, pl. 6, figs. 7*a–c*.

Description. Test small, subcircular in outline, almost planoconvex, umbilico-convex, coiled in a low trochospire ; dorsal side flat although the early chambers are slightly inflated and weakly raised above the circumambient, last whorl ; ventral side strongly inflated and distinctly protruding ; equatorial periphery subcircular, moderately lobate, with a single, delicately beaded marginal keel ; axial periphery acute ; chambers on the dorsal side 18, arranged in 3 dextrally coiled whorls ; the initial ones are very small, globigerine and weakly inflated, they increase slowly in size and are followed by slightly larger, globular, inflated chambers which increase moderately in size ; the last whorl is composed of 6 relatively large, crescentic chambers which increase slowly in size except for the last one which is slightly smaller than the penultimate ; on the ventral side the chambers are 6, subglobular, strongly inflated, distinctly protruding and increase slowly in size ; sutures on the dorsal side curved, slightly raised and delicately beaded ; on the ventral side they are radial and strongly depressed ; umbilicus roughly hexagonal in outline, relatively large, deep and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal-umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate, except for the imperforate keel, peripheral band and tegilla ; surface rough, especially on the ventral side where it is coarsely papillose in the early part, with the roughness decreasing gradually towards the last chamber ; the papillae sometimes taper out simulating thick spine-like projections especially along the periphery.

Dimensions of described specimen.

Maximum diameter = 0·35 mm.
Minimum diameter = 0·29 mm.
Thickness = 0·24 mm. (of last chamber)

Remarks. *Globotruncana gansseri subgansseri* was first described by Gandolfi (1955) who remarked that this subspecies differs from *G. gansseri gansseri* in having a smaller test, a greater number of chambers in the last whorl, more inflated chambers, and a less evident keel.

Globotruncana gansseri subgansseri is believed to have evolved from *G. gansseri*

gansseri Bolli, and may possibly represent a transitional stage between the latter and *G. lugeoni* Tilev, although no direct evidence was recorded.

HYPOTYPE. P.45544.

HORIZON AND LOCALITY. Figured specimen from sample No. 16, Gebel Owaina section.

STRATIGRAPHICAL RANGE. Gandolfi (1955) described *G. gansseri subgansseri* from the Colon shale of northeastern Colombia where its range was described as fairly rare in the uppermost *Siphogenerinoides bramlettei* Zone which he considered to be of Maestrichtian age.

In the Esna–Infu region, *G. gansseri subgansseri* appears as a rare to common form in the Middle Maestrichtian *G. gansseri* Zone. It increases gradually upwards in the section to flood the basal part of the overlying *G. esnehensis* Zone and then dies out completely near the middle part of this zone.

Globotrunana havanensis Voorwijk

1937 *Globotruncana havanensis* Voorwijk : 195, pl. 1, figs. 25, 26, 29.
? 1946 *Globorotalia pshadae* Keller : 99, pl. 2, figs. 4–6.
1951 *Globotruncana citae* Bolli : 197, pl. 35, figs. 4–6.
? 1953 *Globotruncana citae* Bolli ; Papp & Küpper : 38, pl. 1, figs. 4*a–c*.
? 1953 *Globorotalia pshadae* Keller ; Subbotina : 204, pl. 16, figs. 1*a*–6*c*.
1954 *Globotruncana citae* Bolli ; Ayala : 387, pl. 3, figs. 2*a–c*.
1954 *Globotruncana havanensis* Voorwijk ; Ayala : 396, pl. 6, figs. 2*a–c*.
1955 *Globotruncana citae* Bolli : Gandolfi : 51, pl. 3, figs. 11*a–c*.
1956 *Globotruncana citae* Bolli ; Knipscheer (in Ganss & Knipscheer) : 624, pl. 2, figs. 3*a–c*.
1956 *Rugotruncana havanensis* (Voorwijk) Brönnimann & Brown : 552, pl. 22, figs. 4–6, pl. 24, fig. 5.
1956*b* *Marginotruncana citae* (Bolli) Hofker : 334, text-fig. 25.
1956*c* *Marginotruncana citae* (Bolli) ; Hofker : 79, text-fig. 72.
1957 *Globotruncana* (*Globotruncana*) *citae* Bolli ; Edgell : 111, pl. 1, figs. 13–15.
1960*a* *Globotruncana citae* Bolli ; Hofker : 225, text-figs. 20*a–c*.
1960 *Globorotalia pshadae* Keller ; Vinogradov : 307, pl. 2, figs. 15*a*–16*b*.
1962 *Praeglobotruncana* (*Praeglobotruncana*) *havanensis* (Voorwijk) Berggren : 26–30, pl. 7, figs. 1*a–c*.

REMARKS. The taxonomic position of this species has been very much confused ; it was defined as a *Globotruncana* by Voorwijk (1937), as a *Globorotalia* by Keller (1946), Subbotina (1953) and Vinogradov (1960), as a *Rugotruncana* by Brönnimann & Brown (1956) and Pessango (1960), as *Marginotruncana* by Hofker (1956*b*, *c*) and as *Praeglobotruncana* by Bolli (1957*a*) and Berggren (1962). However, the few specimens recorded in the present study clearly show that the aperture is interiomarginal, umbilical, covered by complex tegilla of which remnants are still preserved, and thus prove that the species should be assigned to the genus *Globotruncana*.

HYPOTYPES. P.45657–58.

HORIZON AND LOCALITY. Hypotypes from sample 23, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globotruncana havanensis* was first described by Voorwijk (1937) from the Upper Cretaceous of Habana, Cuba. It was also recorded from the Maestrichtian of the Caucasus (Keller 1946 and Subbotina 1953), the Maestrichtian of Trinidad (Bolli 1951, 1957*a*), of Austria (Papp & Küpper, 1953), of northeastern Colombia (Gandolfi 1955), of Bavaria (Knipscheer 1956), of Texas and of Cuba (Brönnimann & Brown 1956), of northwestern Germany and of Holland (Hofker 1956*b*, *c*), of Australia (Edgell 1957), of Romania (Vinogradov 1960) and of southern Scandinavia (Hofker 1960*a* and Berggren, 1962).

In the Esna–Idfu region, *G. havanensis* occurs as a rare form throughout the Maestrichtian, increasing gradually upwards in the section, and dying out completely below the disconformity separating the Maestrichtian from the overlying Danian.

Globotruncana leupoldi Bolli

(Pl. 1, figs. 4*a*–*c*)

1945 *Globotruncana leupoldi* Bolli : 235, pl. 9, fig. 17 ; text-fig. 1, figs. 25, 26.

DESCRIPTION. Test medium-sized, subcircular in outline, biconvex, coiled in a moderately high trochospire ; dorsal side broadly convex, moderately raised, ventral side convex and moderately inflated ; equatorial periphery subcircular, distinctly lobate, with two well-developed, thickened, delicately beaded and widely spaced marginal keels, becoming single on the last chamber only ; axial periphery truncate in the early part, angular and distinctly acute in the later part ; chambers on the dorsal side 16, arranged in 3 dextrally coiled whorls ; the initial chambers are small, inflated, globigerine, increasing moderately in size and followed by typically crescentic, petaloid chambers which increase slowly in size as added ; the last whorl is composed of 5 large, typically crescentic, petaloid chambers which are elongated in the direction of coiling and increase slowly in size ; on the ventral side the chambers are 5, large, roughly ovoid and distinctly outlined with horseshoe-shaped, beaded ridges and increase slowly in size ; sutures on the dorsal side are curved, raised and beaded ; on the ventral side they are strongly curved forward, thickened, raised and beaded ; umbilicus pentagonal in outline, wide, deep, bordered by raised, beaded ridges and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate, except for the imperforate keels, peripheral band and tegilla ; surface smooth.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·45 mm.
Minimum diameter = 0·37 mm.
Thickness = 0·22 mm.

REMARKS. Bolli (1945) described *G. leupoldi* from thin sections only and included in its synonymy some of the forms previously described by de Lapparant (1918) as *Rosalina linnei* d'Orbigny " type 5 " and *Rosalina stuarti*, although the latter is a completely distinct form. He also considered some of the forms described by Vogler

(1941) as *Globotruncana linnei stuarti* Vogler and *G. linnei marginata* (Reuss) to belong to *G. leupoldi*.

Reichel (1950) considered *G. leupoldi* as a junior synonym of *G. arca* (Cushman) while Papp & Küpper included it in the synonymy of *G. fornicata* Plummer, and Brönnimann & Brown (1956) followed by Berggren (1962) in that of *G. rosetta* (Carsey). However, *Globotruncana leupoldi* is too remote to be related to either *G. fornicata* or *G. rosetta*. It is distinguished from typical *G. arca*, from which it is thought to have evolved, by its smaller, slightly compressed test, fewer chambers, less beaded keels and sutures, sharply acute axial periphery on the last chamber and truncate one on the early chambers, its flattened petaloid last chambers on the dorsal side, its single keel on the last one or two chambers and its perfectly smooth surface.

The form described by Olsson (1960) as *G. leupoldi* is probably *G. arca* or is transitional to it.

Hypotype. P.45545.

Horizon and locality. Figured specimen, from sample No. 18, W. El-Sharawna section.

Stratigraphical range. *Globotruncana leupoldi* was described by Bolli (1945) from the Wangschichten limestone of Switzerland where it was found to range throughout the Upper Campanian–Maestrichtian.

In the Esna–Idfu region *G. leupoldi* ranges throughout the *G. fornicata* and the *G. gansseri* Zones. It fades out gradually towards the top part of the latter zone and dies out completely in the basal part of the overlying *G. esnehensis* Zone.

Globotruncana lugeoni Tilev

(Pl. 6, figs. 1*a–d* ; Pl. 11, fig. 2)

1951 *Globotruncana lugeoni* Tilev : 41–46, pl. 1, figs. 5, 6, text-figs. 10*a–c*, 11*a–d*, ? 12*a–e*. (See also Tilev 1952 where figures are repeated.)

Description. Test large, planoconvex, coiled in a very low trochospire ; dorsal side almost flat and slightly imbricate although the chambers are slightly inflated and moderately overlapping ; ventral side strongly inflated and distinctly protruding; equatorial periphery roughly ovoid, elongate, slightly lobate, with a single well-developed, heavily beaded marginal keel which is slightly shifted towards the dorsal side ; axial periphery subangular ; chambers on the dorsal side about 18, arranged in 3½ dextrally coiled whorls, increasing very slowly in size ; initial chambers small subglobular, weakly inflated and almost masked by the surface rugosity ; they are followed by slightly larger subglobular chambers ; the last whorl is composed of 6 subcircular, weakly inflated chambers ; on the ventral side the chambers are 6, subglobular, strongly inflated, distinctly protruding and increase so slowly in size that they all appear to be roughly equal except for the last ; sutures on the dorsal side slightly curved, depressed in the early part, strongly curved, raised, thickened and heavily beaded in the later part, although the slight inflation of the chambers makes them appear slightly depressed towards the inner whorl ; on the ventral side the sutures are radial and strongly incised ; umbilicus roughly hexagonal in outline, moderately wide, deep and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla, with accessory apertures, only poorly preserved ; wall calcareous, perforate, except for the imperforate keel and tegilla ; surface rough, heavily nodose in the early part especially on the ventral side, with the roughness decreasing gradually towards the last chamber.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·43 mm.
Minimum diameter = 0·34 mm.
Maximum thickness = 0·26 mm. (Thickness of last chamber)

MAIN VARIATION.

1. Chambers 13–18, arranged in $2\frac{1}{2}$–$3\frac{1}{2}$ whorls, generally dextrally coiled (all specimens studied coiled dextrally).
2. Chambers in the last whorl 4–7.

REMARKS. Brönnimann & Brown (1956) followed by Berggren (1962) considered this species to be a junior synonym of *G. gansseri gansseri* Bolli. However, the present study showed clearly that the two forms are morphologically distinct and should be treated separately.

The evolutionary history of *G. lugeoni* Tilev is not clear, but it might have evolved from *G. gansseri gansseri*, although no direct evidence was recorded.

Tilev (1951, 1952) also described as *G. lugeoni* var. *angulata*, a form which appears to be quite distinct from the holotype of *G. lugeoni* and the studied hypotypes. It appears to be more closely related to *G. stuarti stuarti* (de Lapparent), although it lacks the characteristic shape of the chambers of the latter species on the ventral side. Forms identical with this variety were recorded in the samples studied, but being very rare they are not described for the time being.

HYPOTYPE. P.45546.

HORIZON AND LOCALITY. Figured specimen, from sample No. 15, Gebel Owaina section.

STRATIGRAPHICAL RANGE. Tilev (1951, 1952) recorded *G. lugeoni* from the Maestrichtian of southeastern Turkey stating that its range is more precisely considered as Middle Maestrichtian. In the Esna–Idfu region, G. *lugeoni* Tilev occurs as a rare form in the *G. gansseri* Zone. It gradually increases upwards in the section to flood the upper part of this zone and then fades out gradually in the basal part of the overlying *G. esnehensis* Zone, where it dies out completely.

Globotruncana mariai Gandolfi

1941 *Rosalinella globigerinoides* Marie : 239, pl. 36, figs. 338*a–c*.
1941 *Rosalinella globigerinoides* var. *sublaevigata* Marie : 240, pl. 36, figs. 339*a–c*.
1955 *Globotruncana mariai* Gandolfi : 33.

REMARKS. Marie (1941) described *Rosalinella globigerinoides* as a new species from the Campanian, " *Belemnitella mucronata* chalk " of the Paris Basin. As *Rosalinella* Marie, is a junior synonym of *Globotruncana* Cushman 1927, the name of the present species was automatically changed to *Globotruncana globigerinoides* (Marie) where it became a junior homonym of *Globotruncana globigerinoides* Brotzen 1936, which in its turn is a junior synonym of *G. cretacea* (d'Orbigny) 1840.

Gandolfi (1955) changed the name of the present species to *Globotruncana mariai* nom. nov. Apparently he named the species after Dr. P. Marie, who first described it, and the spelling should have been *mariei*. Unfortunately, Banner & Blow (1960) proposed the name *G. mariei* for *G. cretacea* Cushman 1938, which itself is a junior homonym of *G. cretacea* (d'Orbigny) 1840.

As neither of the names can be changed according to the rules of zoological nomenclature, they are both applied here in spite of the confusion which may result.

Globotruncana mariai is distinguished by its peculiarly shaped, segmented, imbricate double keel and wide peripheral band. Marie (1941) also described as *R. globigerinoides* var. *sublaevigata*, a form which only differs from the central type in having the two marginal keels unequally projecting. Such a minor variation was found to be unworthy of distinction and thus *G. globigerinoides* var. *sublaevigata* is included here within the central type.

HYPOTYPE. P.45547.

HORIZON AND LOCALITY. Hypotype from sample No. 4, Abou Saboun section.

STRATIGRAPHICAL RANGE. This species was originally described from the Campanian of the Paris Basin (Marie 1941). It occurs as a rare to common form in the Lower Maestrichtian *G. fornicata* Zone of the studied sections, and dies out completely in the top part of this zone.

Globotruncana mariei Banner & Blow

1931 *Globotruncana arca* (Cushman) ; Cushman : 59, pl. 11, figs. 6*a–c*.
1931 *Globotruncana arca* (Cushman) ; Plummer, (pars) : 195, pl. 13, figs. 7–8*c* ; non figs. 9*a–c*, 11*a–c*.
1936 *Globotruncana arca* (Cushman) ; Cushman : 419, pl. 1, figs. 14*a–c*.
1938 *Globotruncana cretacea* Cushman ; 67, pl. 11, figs. 6*a–c*.
1939 *Globotruncana cretacea* Cushman ; Cushman : 92, pl. 16, figs. 8*a–c*.
1946 *Globotruncana cretacea* Cushman ; Cushman : 151, pl. 62, figs. 7*a–c*.
1951 *Globotruncana cretacea* Cushman ; Tilev (pars) ; 62–67, text-figs. 21*a–d*, non 20*a–d*. (See also Tilev 1952 where figures are repeated.)
1954 *Globotruncana cretacea* Cushman ; Nakkady & Osman : 79, pl. 19, figs. 10*a–c*.
1960 *Globotruncana mariei* Banner & Blow : 8.

REMARKS. *Globotruncana mariei* was first described by Cushman (1931) as *Globotruncana arca* (Cushman). The same author (1938), realizing the difference between this form and *G. arca*, considered it as a distinct species and named it *G. cretacea* Cushman.

Tilev (1951, 1952) stated that although Cushman (1938) had described his *G. cretacea* as " usually having a single keel ", the holotype, as figured by Cushman was shown to have two closely spaced keels. He also noticed that in the specimens he studied from the Maestrichtian of southeastern Turkey, there were forms with double and single keels. He also considered *G. rosetta rosetta* (Carsey) as a junior synonym of the present species in spite of its priority.

Brönnimann & Brown (1956) confirmed Tilev's earlier observation stating that " In an examination of the holotype of *Glt. cretacea* Cushman, two keels, very close together, were observed in all chambers of the last whorl ". These two authors also considered the present species to be intermediate between *G. lapparenti* Brotzen and *G. rosetta* (Carsey).

Banner & Blow (1960) proved *Globigerina cretacea* d'Orbigny, 1840, to be a true *Globotruncana*, and thus changed its name to *Globotruncana cretacea* (d'Orbigny) whereby *Globotruncana cretacea* Cushman 1938, became a junior homonym, which they renamed *Globotruncana mariei* nom. nov.

Globotruncana mariei is distinguished by its medium-sized, planoconvex to unequally biconvex test, its chambers which increase rapidly in size in the last whorl, its very closely spaced keels, and strongly overlapping chambers on the ventral side, and by its smooth test and somewhat rougher keels.

Contrary to Tilev's observation (1951, 1952), *G. marei* is quite distinct from *G. rosetta rosetta* (Carsey), although Brönnimann & Brown (1956) stated that it seems to be an incipient form of *G. rosetta*.

Nakkady (1951*a*) described as *G. cretacea* Cushman from Duwi, Mellaha, Durba and Danilli sections, Egypt, forms which include *G. stuarti stuartiformis* Dalbiez, *G. aegyptiaca aegyptiaca* Nakkady and *G. gagnebini* Tilev, as examination of his specimens (B.M. N.H., P.41782) has revealed.

Nakkady also figured as *G. pseudocretacea* n.sp., a form which most probably belongs to *G. gagnebini* Tilev, or is transitional between it and *G. ventricosa* White, as examination of his type specimens (B.M.N.H., P.41783–84) has revealed. However, Berggren (1962) wrongly considered *G. pseudocretacea* to be a *nomen nudum* and stated that Nakkady's specimens were related to *G. rosetta rosetta* (Carsey).

HYPOTYPE. P.45548.

HORIZON AND LOCALITY. Hypotype from sample No. 18, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. *Globotruncana mariei* was first described from the Upper Campanian, Selma chalk of Tennessee. Most records show that it ranges throughout the Upper Campanian and the Maestrichtian.

In the Esna–Idfu region, *G. mariei* occurs as a common form throughout the Maestrichtian, *G. fornicata*, *G. gansseri* and *G. esnehensis* Zones, being most common at the base and fading out gradually upwards in the section.

Globotruncana orientalis sp. nov.

(Pl. 12, figs. 4*a–d*)

DIAGNOSIS. A *Globotruncana* with broadly arched dorsal side and almost flat ventral one, two closely spaced keels in early part, reduced to one in the last chambers;

curved, raised, beaded sutures, wide umbilicus and horseshoe-shaped ridge of beads bordering each chamber on ventral side.

DESCRIPTION. Test large, almost circular in outline, coiled in a relatively high trochospire ; dorsal side broadly convex, ventral side flat although the chambers are very slightly inflated ; equatorial periphery almost circular, slightly lobate ; axial periphery angular, acute, with two heavily beaded keels on the early chambers of the last whorl, reduced to a single, well-developed, distinctly beaded keel in the last chambers ; chambers on the dorsal side 18 (17 + 1 broken), arranged in 3 dextrally coiled whorls and slowly and regularly increasing in size ; the initial chambers are small, inflated and globigerine, while later chambers are typically crescentic, slightly flattened and elongated in the direction of coiling, the last whorl is composed of 6 large, typically crescentic chambers ; on the ventral side the chambers are 6, ovoid, very weakly inflated, slightly overlapping, distinctly outlined with heavily beaded horseshoe-shaped rims, and increase so slowly in size that they all appear to be roughly equal ; sutures on both sides curved, raised, thickened and heavily beaded ; umbilicus roughly hexagonal in outline, wide, deep, surrounded by slightly raised, heavily beaded ridges, and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate, except for the imperforate keels, peripheral band and tegilla ; surface generally smooth.

DIMENSIONS OF HOLOTYPE.

Maximum diameter = 0·50 mm.
Minimum diameter = 0·45 mm.
Thickness = 0·25 mm.

MAIN VARIATION.

1. Chambers on the dorsal side 18–21, arranged in 3–3½ whorls, generally dextrally coiled.
2. The last whorl is composed of 5–7 chambers which are large, crescentic and increase slowly in size.
3. In some specimens the ventral keel is completely reduced and the test becomes entirely single keeled at least throughout the last whorl.

REMARKS. *Globotruncana orientalis* is morphologically similar to *G. leupoldi* Bolli, *G. conica* White, *G. esnehensis* Nakkady & Osman and to *G. sharawnaensis* sp. nov. However, it is distinguished from *G. leupoldi* by its flat ventral side, much narrower peripheral band and less lobate equatorial periphery. It differs from *G. conica* White by its less conical dorsal side, its early double keel and the horseshoe-shaped ridges on the ventral side. *Globotruncana esnehensis* is entirely single keeled and has strongly depressed ventral sutures, while *G. sharawnaensis* sp. nov. is single keeled in the early part becoming double keeled later, has depressed ventral sutures and a rougher surface.

The forms desribed by Cita (1948) and Pessagno (1962) as *G. conica* White most probably belong to the present species.

Globotruncana orientalis sp. nov. has possibly evolved from *G. arca* (Cushman) by the flattening of the ventral side and the reduction of the ventral keels on the last chambers. This is substantiated by the fact that such tendencies were clearly observed in specimens of *G. arca* (Cushman). On the other hand, *G. orientalis* has probably evolved into *G. esnehensis* Nakkady & Osman, although no direct evidence was recorded.

HOLOTYPE. P.45549.

PARATYPES. P.45550.

HORIZON AND LOCALITY. Holo- and paratypes from sample No. 18, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. *Globotruncana orientalis* sp.nov. appears as a common to abundant form in the Lower Maestrichtian *G. fornicata* Zone of the sections studied. It continues as an abundant form in the overlying *G. gansseri* Zone, fading out gradually towards its top, and dies out completely in the basal part of the *G. esnehensis* Zone.

Globotruncana rosetta pettersi Gandolfi

1955 *Globotruncana rosetta pettersi* Gandolfi : 68, pl. 6, figs. 3*a*–4*c*, text-fig. 11*a*.
1961 *Globotruncana* cf. *rosetta pettersi* Gandolfi ; Corminboeuf : 113–114, pl. 1, figs. 3*a*–*c*.

REMARKS. *Globotruncana rosetta pettersi* was first described by Gandolfi (1955) as a new subspecies from the lower Colon shale of northeastern Colombia where he considered its range as Campanian. He stated that the form is entirely single keeled, but examination of topotype specimens kindly sent by him to the present author, showed forms with 2 keels on the early part of the last whorl, becoming single keeled on the later chambers, and others with an entirely single keeled last whorl. The entirely single keeled form is similar to the *G. gansseri* group, especially to *G. gansseri gandolfii* subsp. nov. from which it is only distinguished by its smooth surface. Gandolfi also stated that *G. rosetta pettersi* was found to disappear when the first *G. gansseri gansseri* starts, but in the present study *G. rosetta pettersi* occurs as a common form in the lower part of the *G. gansseri* Zone. It was neither recorded in the underlying *G. fornicata* Zone nor in the upper part of the *G. gansseri* Zone. This clearly indicates that the range of this subspecies is only Middle Maestrichtian, while Gandolfi considered it as Campanian. However, as previously mentioned, the Colon shale, which Gandolfi considers as Campanian–Maestrichtian, most probably belongs to the Maestrichtian alone, as suggested by its planktonic foraminiferal content. This is substantiated by the fact that the present subspecies was also recorded from the Maestrichtian of Switzerland as *G.* cf. *rosetta pettersi* Gandolfi by Corminboeuf (1961).

HYPOTYPE. P.45551.

HORIZON AND LOCALITY. Hypotype from sample No. 23 W. El-Sharawna section.

Globotruncana rosetta rosetta (Carsey)

(Pl. 8, figs. 3*a–d*)

1926 *Globigerina rosetta* Carsey : 44, pl. 5, figs. 3*a–c*.

1931 *Globotruncana arca* (non Cushman) ; Plummer (pars) : 195, pl. 13, figs. 9*a–c*, 11*a–c* (non figs. 7*a–c*, 8*a–c*).

? 1937*a* *Globotruncana rosetta* (Carsey) Glaessner : 39, pl. 1, figs. 12*a–c*.

? 1951 *Globotruncana rosetta* (Carsey) : Bandy : 509, pl. 75, figs. 4*a–c*.

? 1951 *Globotruncana cretacea* Cushman ; Tilev (pars) 62–67, text-figs. 20*a–d*, non 21*a–d* (see also Tilev 1952 where figures are repeated).

? 1954 *Globotruncana rosetta* (Carsey) ; Nakkady & Osman : 84, pl. 19, figs. 7*a–c*.

? 1955 *Globotruncana rosetta rosetta* (Carsey) ; Gandolfi : 66–67, pl. 6, figs. 1*a–c*, text-figs. 10*a–c*.

? 1955 *Globotruncana bollii* Gandolfi : 62–63, pl. 5, figs. 1*a–c*.

1956 *Globotruncana rosetta* (Carsey) : Brönnimann & Brown : 545–546, pl. 21, figs. 11–13.

1962 *Globotruncana rosetta* (Carsey) : Barr : 575, pl. 70, figs. 4*a–c*.

DESCRIPTION. Test large, planoconvex, coiled in a very low trochospire ; dorsal side almost flat, ventral side distinctly protruding ; equatorial periphery subcircular, moderately lobate, with two very closely spaced keels on the early part of the last whorl reduced to a single keel on the later chambers ; axial periphery angular with the ventral side almost at right angles to the flat periphery ; chambers on the dorsal side 18, arranged in 3 dextrally coiled whorls ; the initial chambers are small, inflated, globigerine, increasing slowly in size, and followed by typically crescentic, flattened chambers which increase moderately in size ; the last whorl is composed of 6, relatively large, typically crescentic, flattened chambers which increase slowly in size ; on the ventral side the chambers are 6, relatively large, angular conical, strongly inflated, slightly overlapping, distinctly protruding and increase so slowly that they appear to be all roughly equal in size ; sutures on the dorsal side curved, slightly raised and delicately beaded with the beading fading out gradually towards the last chamber ; on the ventral side the sutures are radial and slightly depressed ; umbilicus roughly stellate in outline, relatively wide, deep, bordered by delicately beaded ridges and covered by complex tegilla of which remnants are preserved ; primary apertures interiomarginal, umbilical ; tegilla, with accessory apertures, only poorly preserved ; wall calcareous, perforate, except for the imperforate keels, peripheral band and tegilla ; surface delicately papillose especially on the ventral side and in the early part becoming smoother towards the last chamber.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter	=	0·52 mm.
Minimum diameter	=	0·47 mm.
Maximum thickness	=	0·30 mm.

VARIATION. The main variation observed is in the degree of flattening of the dorsal side, protrusion of the ventral side, and surface rugosity.

REMARKS. *Globotruncana rosetta rosetta* was first described by Carsey (1926) as *Globigerina rosetta* n.sp. White (1928) transferred this species to the genus *Globotruncana* although his figured specimen probably belongs to the *G. stuarti* group. Plummer (1931) considered the present species to belong to *G. arca* (Cushman) suggesting that the two keeled specimens are juvenile forms while the single keeled ones are mature. Since then *G. rosetta rosetta* has been quite often confused with *G. arca* Cushman, *G. marginata* (Reuss), *G. stuarti* (de Lapparent) and *G. cretacea* Cushman (= *G. mariei* Banner & Blow 1960).

Tilev (1951, 1952) included *G. rosetta rosetta* (Carsey) in the synonymy of *G. cretacea* Cushman 1938 (= *G. mariei* Banner & Blow 1960) although the former has priority. Brönnimann & Brown (1956) partially substantiating Tilev's observation, stated that " Examination of the holotype of *Globotruncana rosetta* (Carsey), in the Carsey collection at the University of Texas, reveals that it possesses two keels in the early chambers of the last whorl which are very close together. In the ante- and penultimate chambers the two keels join ". These two authors also added " In an examination of the holotype of *Glt. cretacea* Cushman, two keels, very close together, were observed in all chambers of the last whorl. It is intermediate between *Glt. lapparenti* Brotzen and *Glt. rosetta* (Carsey). It seems to be an incipient form of *Glt. rosetta*, for all transitions exist between forms corresponding to the holotypes of *Glt. rosetta* and *Glt. cretacea*. We suggest that the forms which exhibit two keels, close together in all chambers of the last whorl be referred to *Glt. cretacea* Cushman, and that the forms which exhibit two keels close together in the early chambers of the last whorl and only one keel in the final one or two chambers be referred to *Glt. rosetta* (Carsey) ". They also included *G. leupoldi* Bolli in the synonymy of *G. rosetta* (Carsey). However, the present study has clearly shown that *G. rosetta rosetta* (Carsey), *G. cretacea* Cushman (= *G. mariei* Banner & Blow) and *G. leupoldi* Bolli are separate and distinct forms.

Gandolfi (1955) described as new subspecies of *G. rosetta* (Carsey), two distinct forms which he named *Globotruncana rosetta insignis* Gandolfi and *Globotruncana rosetta pettersi* Gandolfi, thus changing the name of the present form to *Globotruncana rosetta rosetta* (Carsey). He did not state whether his *G. rosetta rosetta* had a double keel on the early part or not, and his *G. rosetta insignis* appears to be synonymous with *G. fareedi* sp. nov., as mentioned earlier (p. 101). Gandolfi also described as *G. bollii* n. sp., a form which may possibly be a junior synonym of *G. rosetta rosetta* (Carsey). Moreover, he suggested that *G. rosetta rosetta* evolved from *G. thalmanni thalmanni* through *G. bollii* into *G. rosetta pettersi* and *G. rosetta insignis*, while Berggren (1962) suggested that *G. rosetta* evolved from *G. mariei*. However, the evolutionary development of *G. rosetta rosetta* is not yet clearly understood. It may have evolved from *G. concavata* (Brotzen) or from *G. ventricosa* White as suggested by the morphological features and stratigraphical ranges of these species, but no direct evidence was recorded. On the other hand, *G. rosetta rosetta* probably evolved into *G. gansseri gansseri* (Bolli) as well as giving rise to *G. rosetta pettersi*.

HYPOTYPE. P.45552.

HORIZON AND LOCALITY. Figured specimen from sample No. 16, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. Carsey (1926) described the holotype of *G. rosetta* from the upper Taylor marl (Upper Campanian of Texas), but apparently she had confused this form with various other species and thus confused its range which she stated to be Cenomanian–Maestrichtian. However, all reliable records show that the present subspecies ranges throughout the Upper Campanian–Middle Maestrichtian only. In the Esna–Idfu region, *G. rosetta rosetta* (Carsey) occurs as an abundant form in the Lower Maestrichtian *G. fornicata* Zone, decreasing gradually upwards in the section and becoming common or rare in the lower part of the overlying *G. gansseri* Zone, where it dies out completely.

Globotruncana sharawnaensis sp. nov.

(Pl. 12, figs. 3*a–d*)

DIAGNOSIS. A *Globotruncana* with large, spiroconvex test, single keel in early part becoming double in last chamber, depressed ventral sutures and delicately papillose surface on ventral side.

DESCRIPTION. Test large, coiled in a high trochospire ; dorsal side broadly convex and highly arched, ventral side almost flat, very slightly raised and weakly inflated ; equatorial periphery subcircular, slightly lobate, with a single, well-developed, beaded keel on the early chambers of the last whorl and two distinct, closely spaced, beaded keels on the last chamber ; axial periphery angular in the early part, truncate on the last chamber, where the two marginal keels are very close and enclose a very narrow peripheral band ; chambers on the dorsal side 21, arranged in 3 dextrally coiled whorls and increase slowly in size ; the initial chambers are small, inflated, globigerine, and are followed by roughly quadrangular to crescentic chambers ; the last whorl is composed of 6½, large chambers, which are generally crescentic to quadrilateral ; on the ventral side the chambers are 6½, roughly ovoid to somewhat quadrangular, weakly inflated, slightly overlapping, and increase slowly in size; sutures on the dorsal side are curved, raised and beaded in the early part and short, very slightly curved to almost straight, raised and beaded in the later ; on the ventral side the sutures are almost straight, radial and depressed in the early part, slightly curved forward and depressed later ; umbilicus polygonal in outline, wide, deep, surrounded by slightly raised, delicately beaded ridges and covered by complex, tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous perforate except for the imperforate keels, peripheral band and tegilla ; surface smooth on the dorsal side, papillose on the ventral, with the papillae fading out gradually on the last two chambers.

DIMENSIONS OF HOLOTYPE.

Maximum diameter	=	0·50 mm.
Minimum diameter	=	0·40 mm.
Thickness	=	0·28 mm.

MAIN VARIATION.

1. Chambers 18–22, arranged in 3–3½ whorls, generally dextrally coiled.
2. The last whorl is composed of 6–7 chambers.

3. In some specimens the partly developed secondary keel is completely reduced leading to forms with a single keel throughout the last whorl.

Remarks. *Globotruncana sharawnaensis* is unique among the known *Globotruncana* species, inasmuch as it shows a single keel on the early part of the last whorl and a double keel on the last one or two chambers. The tendency to reduce the ventral keel in double-keeled globotruncanas was clearly observed in various species which normally show a double keel in the early part of the test and become single keeled later (i.e. reduction by palingenesis). However, no species has yet been recorded as having a single keel in the early stage and a double keel later, although reduction of the ventral keel by proterogenesis would produce such forms.

Forms of *G. sharawnaensis*, with an entirely single keel appear to be somewhat similar to *G. conica* White. However, *G. sharawnaensis* is distinguished from *G. conica* by its slightly smaller test, less conical dorsal side and slightly more protruding ventral one, its somewhat rough ventral side, partially developed ventral keel and acute axial periphery. It differs from *G. orientalis* sp. nov. in its depressed ventral sutures, the character of its keels and the slightly rougher surface on the ventral side. *Globotruncana esnehensis* Nakkady & Osman is distinguished from *G. sharawnaensis* sp. nov. by its dome-shaped test, less protuding and more undulating ventral side, more inflated chambers on the dorsal side, wider umbilicus, smoother surface, and entirely single keel.

Very little is known about the evolutionary history of *G. sharawnaensis* sp. nov. However, it may have evolved from *G. arca* (Cushman) into *G. conica* White and/or *G. esnehensis* Nakkady & Osman, although no direct evidence was recorded.

Holotype. P.45553.

Paratypes. P.45554.

Horizon and locality. Holo- and paratypes, from sample No. 20, W. El-Sharawna section.

Stratigraphical range. *Globotruncana sharawnaensis* sp. nov. is common in the Middle Maestrichtian *G. gansseri* Zone of the studied sections, and dies out completely in the basal part of the overlying *G. esnehensis* Zone.

Globotruncana stuarti parva Gandolfi

(Pl. 9, figs. 2*a–d*)

1951 *Globotruncana stuarti* (de Lapparent) ; Bolli : 196, pl. 34, figs. 10–12.
1951 *Globotruncana stuarti* (de Lapparent) ; Tilev (pars) ; 34–41, text-figs. 8*a–d* non 7*a–d*, non 9*a–d*. (See also Tilev 1952 where figures are repeated.)
1955 *Globotruncana stuarti parva* Gandolfi : 65, pl. 5, figs. 7*a–c*.
1956 *Globotruncana aegyptiaca* Nakkady ; Said & Kenawy : 150, pl. 5, figs. 19*a–c*.

Description. Test small, subcircular, unequally biconvex, dorsal side very slightly raised or nearly flat with a slightly raised part in the centre from which the surface gently slopes radially towards the periphery ; ventral side strongly protruding ; periphery subcircular in outline, nearly continuous, transversely acute, with a single well-developed beaded keel ; chambers on the dorsal side 20, arranged in 4 dextrally-coiled whorls ; the initial chambers are very small, slightly inflated, globigerine, and are followed by nearly crescentic chambers which increase very slowly in size till near the beginning of the last whorl where they enlarge very rapidly ; the last whorl is composed of 4, large, angular conical chambers which are narrow and strongly elongated in the direction of coiling ; the first one is typically crescentic on the dorsal side, while the last 3 are roughly trapezoidal ; on the ventral side the chambers are 4½, typically quadrangular with blunt corners and roughly parallel curved sides ; they are strongly overlapping, distinctly outlined, and strongly inflated especially around the umbilicus, with the surface somewhat steeply sloping towards the thinned-out periphery ; sutures on the dorsal side very slightly curved or nearly straight, angular, limbate, raised and heavily beaded ; on the ventral side they are strongly curved forward, limbate, raised and heavily beaded ; umbilicus, narrow, roughly pentagonal in outline, relatively deep, surrounded by thickened, raised, beaded ridges, and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical, tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate, except for the imperforate keel and tegilla ; surface smooth and finely porous.

Dimensions of described specimen.

Maximum diameter = 0·46 mm.
Minimum diameter = 0·36 mm.
Thickness = 0·26 mm.

Main variation.

1. Chambers on the dorsal side 15–20 arranged in 3–4 whorls, usually dextrally coiled (of 75 specimens picked at random, 2 coiled sinistrally).
2. Chambers in the last whorl 4–5, the first one or two usually crescentic, the last three trapezoidal and much bigger.
3. The surface is generally smooth but in some specimens small scattered papillae cover the surface of the initial chambers.

Remarks. *Globotruncana stuarti parva* Gandolfi has always been confused with *G. stuarti stuarti* (de Lapparent), from which it is believed to have evolved. However, it can be clearly distinguished by its much smaller size, fewer chambers in the last whorl, its nearly straight sutures on the dorsal side, its strongly protruding umbilical side, and by the fact that the last whorl is always much larger than the rest of the test.

Hypotype. P.45555.

Horizon and locality. Figured specimen from sample No. 23, W. El-Sharawna section.

Stratigraphical range. *Globotruncana stuarti parva* Gandolfi is recorded from the lower part of the *G. gansseri* Zone of the studied sections, where it is found in great abundance in association with *G. stuarti stuarti*, *G. stuarti stuartiformis* and *G. stuarti subspinosa*. A few meters higher in the succession, all the other subspecies disappear, but *G. stuarti parva* continues as a common to rare form in the overlying *G. esnehensis* Zone.

Gandolfi (1955) described *G. stuarti parva* from the Colon shale of northeastern Colombia, and considered its range as Campanian–Maestrichtian. However, the distribution of *Globotruncana* species in the Colon shale seems to indicate that the whole formation is Maestrichtian in age as not a single exclusively Upper Campanian species is present even in the lowest part.

G. stuarti parva was also recorded from the Maestrichtian rocks of Trinidad (Bolli 1951) and of southeastern Turkey (Tilev 1951, 1952) where it was lumped with *G. stuarti stuarti*.

Globotruncana stuarti stuarti (de Lapparent)

(Pl. 8, figs. 4*a–d* ; Pl. 9, figs. 1*a–d*)

1918*b* *Rosalina stuarti* de Lapparent : 11–14, pl. 1, figs. 5, 6, 7, text-figs. 4, 5.
1928 *Globotruncana rosetta* (Carsey) ; White : 286, pl. 39, figs. 1*a–c*.
1941 *Globotruncana stuarti* (de Lapparent) Vogler : 289, pl. 23, figs. 40–43.
1941 *Globotruncana linnei stuarti* Vogler (pars) : 289, pl. 24, fig. 8, non figs. 9–13.
1945 *Globotruncana stuarti* (de Lapparent) ; Bolli : 236, pl. 9, fig. 18, text-fig. 1 (27, 28).
1948 *Globotruncana stuarti* (de Lapparent) ; Cita : 160–161, pl. 4, figs. 7*a–c*.
1949 *Globotruncana* (*Globotruncana*) *stuarti* (de Lapparent) ; Reichel : 613–615, pl. 16, fig. 10, pl. 17, fig. 10, text-fig. 7*a*.
1951*a* *Globotruncana arca* (Cushman) ; Nakkady (pars) : 56–57, pl. 1, fig. 4A, non B–E.
1951 *Globotruncana* (*Globotruncana*) *stuarti* (de Lapparent) ; Noth : 78, pl. 8, figs. 12*a–c*.
? 1951 *Globotruncana* (*Globotruncana*) *rosetta* (Carsey) ; Noth : 78, pl. 8, figs. 13*a–c*.
1951 *Globotruncana stuarti* (de Lapparent); Tilev (pars) : 34–41, pl. 1, fig. 3, text-figs. 7*a–d*, non figs. 8*a–d*, 9*a–d* (see also Tilev 1952 where figures are repeated).
1952 *Globotruncana stuarti* (de Lapparent) ; Sigal : 40, text-fig. 42.
1955 *Globotruncana* (*Globotruncana*) *stuarti* (de Lapparent) ; Dalbiez : 163–164, Chart 2, text-figs. 4*a–c*.
1955 *Globotruncana stuarti stuarti* (de Lapparent), Gandolfi : 64–65, pl. 5, figs. 6*a–c*.
1956 *Globotruncana stuarti* (de Lapparent) ; Knipscheer : 52, pl. 4, figs. 19*a*–20*c*, text-figs. 2, 3.
1962 *Globotruncana* (*Globotruncana*) *stuarti stuarti* (de Lapparent) ; Pessagno : pl. 2, figs. 1–3.

EMENDED DIAGNOSIS. A *Globotruncana* with large, circular, biconvex test ; strongly protruding ventral side, and slightly conical dorsal one ; non-lobate entire periphery, axially strongly acute ; thinned-out, continuous, entirely single keel ; large number of chambers (18–28) increasing constantly and regularly in size and strongly elongated in direction of coiling ; large number of whorls (3–4) and large number of chambers in last whorl (6–7) ; shape of last chambers on dorsal side roughly trapezoidal ; strongly overlapping quadrangular chambers on ventral side ; short, slightly curved, raised beaded sutures on both sides.

DESCRIPTION. (Specimen, Pl. 8, figs 4*a–d*.) Test large, very nearly circular, lenticular, nearly equally biconvex ; dorsal side slightly raised, very broadly and gently conical ; ventral side convex, moderately protruding ; equatorial periphery circular, non-lobate, almost entire, with a single, well-developed, beaded keel which slightly weakens on the last chambers ; axial periphery strongly acute ; chambers on the dorsal side 21 arranged in 3½ dextrally coiled whorls ; the initial chambers are small, inflated, globigerine and are followed by crescentic chambers which increase slowly and regularly in size as added ; the last whorl is composed of 6, narrow chambers which increase slowly in size, and are strongly elongated in the direction of coiling ; the first two are nearly crescentic, the last four roughly trapezoidal ; on the ventral side the chambers are 6, typically quadrangular with blunt corners and roughly parallel curved sides ; they are strongly overlapping, distinctly outlined and strongly inflated with the sides gently sloping towards the marginal keel ; sutures on the dorsal side short, slightly curved, raised and delicately beaded ; on the ventral side the sutures are slightly raised and beaded, slightly curved, tending to be nearly straight, except when they curve strongly around the umbilicus to form the umbilical flange ; umbilicus medium sized, hexagonal in outline, relatively deep, surrounded by thickened, raised, beaded ridges, and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate, except for the imperforate keel and tegilla ; surface smooth, with a few small papillae scattered on the ventral side.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·53 mm.
Minimum diameter = 0·48 mm.
Thickness = 0·26 mm.

MAIN VARIATION.

1. The dorsal side is very slightly raised to moderately conical, while the ventral side is always moderately to strongly protruding.
2. Chambers, 18–28, arranged in 3½–4 whorls, generally dextrally coiled.
3. Chambers in the last whorl 6–7, but 5½ and 8 chambers occur as two extremes.

REMARKS. *Globotruncana stuarti stuarti* was first described by de Lapparent (1918) as *Rosalina stuarti* nov. sp. Arni (1933), quite justifiably, removed this species to the genus *Globotruncana*, although his *G.* ? *stuarti* is different from the holotype and paratypes of de Lapparent.

Recently, *G. stuarti* (de Lapparent) was found to include four distinct subspecies which are :

G. stuarti stuarti (de Lapparent) 1918.
G. stuarti parva Gandolfi 1955.
G. stuarti stuartiformis Dalbiez 1955.
G. stuarti subspinosa Pessagno 1960.

The lumping of these subspecies and their transitional forms under *G. stuarti* (de Lapparent), and the confusion between this species and various others, led to disagreement about the diagnostic features and the stratigraphical range of *G. stuarti stuarti*.

Tilev (1952 : 39–41) considered *G. rosetta* (Carsey) to be a variety of *G. stuarti* (de

Lapparent) as he found them together at the same stratigraphical level and they looked the same in thin sections.

Dalbiez (1955 : 163–164) included *G. stuarti* (de Lapparent) with *G. elevata* (Brotzen) and *G. rosetta* (Carsey) in one group, depending on the fact that they are all umbilico-convex and entirely single keeled. However, *G. rosetta* (Carsey) proved to have two closely-spaced keels on the early chambers of the last whorl, joining to form a single keel on the last two chambers. On the other hand, *G. elevata* has a distinctly lobate periphery and typically petalliform chambers as opposed to the entire non-lobate periphery and trapezoidal chambers of *G. stuarti*. With this in mind, Dalbiez (1955 : 169) described *G. elevata stuartiformis* as a new subspecies. However, this form is actually more closely related to *G. stuarti*, hence Pessagno (1960) quite justifiably, changed its name to *G. stuarti stuartiformis* Dalbiez. On the other hand, Pessagno (1960 : 101 ; 1962 : 362) considered *G. elevata* (Brotzen) to be a subspecies of *G. stuarti* and changed its name to *G. stuarti elevata* (Brotzen). However, the morphological characteristics and stratigraphical ranges of these two species strongly favour treating them as two distinct species.

Dalbiez (1955 : 164) suggested that *G. stuarti stuarti* (de Lapparent) had evolved from *G. stuarti stuartiformis* Dalbiez during Upper Campanian time by the development of a biconvex test and by the change of the triangular chambers on the dorsal side into the characteristic trapezoidal form. He also added that the whole group *elevata–rosetta–stuarti* had probably originated from *G. sigali* Reichel of the Lower Turonian, although he had no direct evidence. However, it now seems more logical to suggest that *G. stuarti stuarti* evolved from *G. stuarti subspinosa* in Upper Campanian–Early Maestrichtian time by the development of a more regular test, with a circular, entire periphery and narrow chambers which are strongly elongated in the direction of coiling. On the other hand, *G. stuarti stuarti* is believed to have evolved into *G. stuarti parva* during Lower–Middle Maestrichtian time by the development of a smaller test with fewer chambers in the last whorl, which increase more rapidly in size. These suggestions conform well with the morphological development and stratigraphical ranges of these subspecies, and are substantiated by a whole series of transitional stages between them (see Pl. 9, figs. 1*a–d* ; Pl. 10, figs. 1*a–d*).

Nakkady (1951*a*, pl. 1, fig. 4A) included in *Globotruncana arca*, typical *G. stuarti stuarti* (de Lapparent), as examination of his specimens (B.M.N.H., P.41779) has revealed.

Bolli (1951) described as *G. stuarti* (de Lapparent) a form which is typical of *G. stuarti parva* Gandolfi, while Papp & Küpper (1953) described as *G. stuarti* a form which most probably belongs to *G. elevata* (Brotzen).

Gandolfi (1955) described as *G. stuarti stuarti* (de Lapparent) a form which appears to be transitional between *G. stuarti subspinosa* Pessagno and typical *G. stuarti stuarti*. Such forms were also recorded from the Esna–Idfu region, e.g. Pl. 10, figs. 1*a–d*. Gandolfi also considered *G. conica* White as a subspecies of *G. stuarti* (de Lapparent) and changed its name to *G. stuarti conica* (White). However, Gandolfi's form is different from the holotype of White and is not related to *G. stuarti* (de Lapparent); it needs to be renamed and redescribed in more detail.

Hofker (1956*b* : 322–324) described as *Marginotruncana stuarti* (de Lapparent) a form which is entirely different from *Globotruncana stuarti* as described and figured by de Lapparent. He considered the holotype of *G. stuarti* (de Lapparent) as a *Marginotruncana* (a junior synonym of *Globotruncana* Cushman as mentioned above), and tried to distinguish between *Marginotruncana stuarti* (de Lapparent) and *Globotruncana stuarti* of authors, stating that the form belonging to the genus *Globotruncana* (in his sense) should not be called *stuarti*. He also added, without any obvious reason, that the European specimens are *Marginotruncana stuarti* (de Lapparent), while those from Palestine, Egypt, Trinidad and Texas belong to a different genus (in his own sense, meaning the genus *Globotruncana*). However, as can be seen from his figures, Hofker's *Marginotruncana stuarti* is probably *G. esnehensis* Nakkady & Osman.

HYPOTYPES. P.45556–57.

HORIZON AND LOCALITY. Figured specimens Pl. 8, figs 4*a–d*, Pl. 9, figs. 1*a–d*, from Sample No. 18, W. El-Sharawna section; Pl. 10, figs. 1*a–c*, which is a transitional form between *G. stuarti subspinosa* Pessagno and *G. stuarti stuarti* (de Lapparent), is from Sample No. 16 of the same section.

STRATIGRAPHICAL RANGE. *G. stuarti stuarti* was first described by de Lapparent (1918) from the Maestrichtian rocks of the Hendaye region, southwestern France, and was recorded from the same region by Reichel (1950). All later reliable records are from rocks of Upper Campanian–Maestrichtian age.

In the Esna–Idfu region, *G. stuarti stuarti* (de Lapparent) occurs as a common form in the Lower Maestrichtian *G. fornicata* Zone and continues up to the lower part of the *G. gansseri* Zone, where it is abundant, together with *G. stuarti parva*, *G. stuarti stuartiformis*, and *G. stuarti subspinosa*. Only *G. stuarti parva* continues to the Upper Maestrichtian, the other three subspecies having died out completely. This may suggest that records of *G. stuarti stuarti* (de Lapparent) from the Upper Maestrichtian are probably erroneous. However, Berggren (1962) stated that " valid references to this species indicate its occurrence in the Upper Maestrichtian . " and added " In Scandinavia *G. stuarti* s.s. appears for the first time in the *Pseudotextularia elegans* zone (= *Praeglobotruncana mayaroensis* zone ", but, Berggren's *G. stuarti* (pl. 10, figs 2*a–c*), is not *G. stuarti* (de Lapparent), neither is Reyment's (1960) *G.* cf. *stuarti*, nor Witwicka's (1958) *G. stuarti*, which he used as evidence. Again, *G. stuarti* of Bolli (1951) is actually *G. stuarti parva*, and that of Pessagno (1962) is transitional between *G. stuarti stuarti* and *G. stuarti parva*.

Globotruncana stuarti stuartiformis Dalbiez

(Pl. 9, figs. 3*a–d*)

? 1937*a* *Globotruncana stuarti* (de Lapparent); Glaessner : 39, pl. 1, figs. 13*a–c*.
? 1953 *Globotruncana rosetta* (Carsey); Hagn : 98, pl. 8, figs. 16*a–c*, text-figs. 24, 25.
1953 *Globotruncana stuarti* (de Lapparent); Subbotina : 201, pl. 15, figs. 3*a–5c*.

1955 *Globotruncana* (*Globotruncana*) *elevata stuartiformis* Dalbiez : 169, text-figs. 10*a*–*c*.
1956 *Globotruncana elevata stuartiformis* Dalbiez ; Knipscheer (pars) : 52, pl. 4, figs. 4*a*, *b*, ? 12*a*–*c* ; non figs. 9*a*–10*b*, 14*a*–15*b*.
1960 *Globotruncana* (*Globotruncana*) *stuarti stuartiformis* Dalbiez ; Pessagno : 101, pl. 5, figs. 7, 11.
? 1960 *Globotruncana stuarti* (de Lapparent) ; Vinogradov, 315, pl. 6, figs. 29*a*–30*c*.
1962 *Globotruncana* (*Globotruncana*) *stuarti stuartiformis* Dalbiez ; Pessagno : 362, pl. 2, figs. 4–6.

EMENDED DIAGNOSIS. A single keeled *Globotruncana* with last-formed chambers triangular in shape, moderately lobate periphery, typically straight, raised sutures tangential to preceding whorl on dorsal side, roughly wedge-shaped appearance in side view ; typical stuarti-form chambers on ventral side, and relatively small umbilicus surrounded by raised, thick, beaded ridges.

DESCRIPTION. Test medium-sized, almost planoconvex, coiled in a very low trochospire; dorsal side very slightly convex to nearly flat, gently sloping towards the periphery ; ventral side strongly protruding especially in the later part as the convexity of the ventral side increases gradually towards the last chamber ; equatorial periphery nearly ovoid, moderately lobate ; axial periphery acute, with a single, well-developed, beaded keel ; chambers on the dorsal side 15, arranged in $2\frac{1}{2}$ dextrally coiled whorls ; the initial chambers are small, slightly inflated, globigerine, and are followed by crescentic chambers towards the end of the second whorl ; the last whorl is composed of 5 large chambers, the first two of which are nearly crescentic, while the last three are typically triangular ; on the ventral side the chambers are 5, large, stuarti-form with the sutures more strongly curved forward, thus becoming nearly ovoid, strongly overlapping, distinctly outlined and strongly inflated, with the surface somewhat steeply sloping towards the periphery, especially in the last chambers ; sutures on the dorsal side slightly curved in the early part, nearly straight and tangential to the preceding whorl in the last part, limbate, raised and beaded, with the beading fading out gradually towards the last whorl ; on the ventral side the sutures are strongly curved forward, limbate, raised and faintly beaded ; umbilicus relatively small, roughly hexagonal in outline, moderately deep, surrounded by much thickened, strongly raised, faintly beaded ridges, and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate, except for the imperforate keel and tegilla ; surface smooth.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·51 mm.
Minimum diameter = 0·39 mm.
Thickness = 0·26 mm.

VARIATION. Dalbiez in his original description of *G. stuarti stuartiformis* mentioned a wide range of variation for this subspecies. In the Esna–Idfu region, as we have only the uppermost stages of development of this subspecies, the range of variation is much more limited, and is as follows :

1. Chambers on the dorsal side, 15 to 18, arranged in three dextrally coiled whorls (all the studied specimens coiled dextrally).
2. Chambers in the last whorl, 5–6, compared with 5–9 in the specimens studied by Dalbiez.

REMARKS. Dalbiez (1955 : 169) described *G. stuarti stuartiformis* as a subspecies of *G. elevata* (Brotzen) and named it *G. elevata stuartiformis*. He considered *G. stuarti* of Papp & Küpper (1953 : 39, pl. 2, figs. 2*a*–*c*), which appears to be *G. elevata* (Brotzen), as synonymous with the present subspecies. Both Dalbiez and Berggren (1962) considered the single keeled form, wrongly described as *G. arca* by Cushman (1946 ; pl. 62, figs. 5*a*–*c*), as belonging to this subspecies although it lacks the characteristic triangular last chambers and the straight angular sutures on the dorsal side. However, Dalbiez's subspecies is actually more closely related to the *G. stuarti* group than to *G. elevata* Brotzen as it differs from the latter in the form of the test, the shape of the chambers both on the dorsal and the ventral sides, and in the form of the sutures on both sides.

Pessagno (1960 : 101) followed by Berggren (1962 : 62, 63), realizing this, made *G. elevata stuartiformis* Dalbiez a subspecies of *G. stuarti* (de Lapparent) and changed its name to *G. stuarti stuartiformis* Dalbiez. These authors then went to the other extreme and considered *G. elevata* (Brotzen) as another subspecies of *G. stuarti* (de Lapparent) and changed its name to *G. stuarti elevata* (Brotzen). However, although Glaessner (1937 : 39) considered *G. elevata* (Brotzen) as synonymous with *G. stuarti* (de Lapparent), and Papp & Küpper (1953 : 39, pl. 2, figs. 2*a*–*c*) apparently misidentified *G. elevata* for *G. stuarti*, it has to be mentioned here that *G. elevata* is both morphologically and stratigraphically different from *G. stuarti* and thus should be kept separate and should retain its original name, *G. elevata* (Brotzen).

Dalbiez (1955 : 164) suggested that *G. stuarti stuartiformis* had evolved into *G. stuarti stuarti* (de Lapparent) during Upper Campanian time by the development of a biconvex test and by the change of the triangular chambers on the dorsal side into the characteristic trapezoidal form. However, it seems more probable that *G. stuarti stuartiformis* has evolved into *G. stuarti subspinosa* during Campanian time and that the latter, in its turn, evolved into *G. stuarti stuarti*. The stratigraphical ranges and the diagnostic features of each of these subspecies support this proposition.

Specimens of *G. stuarti stuartiformis* (Dalbiez) from the Esna–Idfu region conform well with the holotype of Dalbiez and with topotypes kindly forwarded by him to the present author, although they are slightly smaller.

HYPOTYPE. P.45558.

HORIZON AND LOCALITY. Figured specimen, from sample No. 18, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. Dalbiez (1955 : 167, 169, chart 2) recorded the approximate range of *G. stuarti stuartiformis* in northeastern Tunisia as Campanian–Lower Maestrichtian, and added that " many specimens identified as *G. stuarti* from the Upper Santonian and Campanian undoubtedly belong to the present subspecies ".

Subbotina (1953 : 201, pl. 15, figs. 3*a*–5*c*) described as *G. stuarti* de (Lapparent) s.l. from the Campanian–Maestrichtian of the northwestern Caucasus, forms which are probably *G. stuarti stuartiformis* Dalbiez as can be seen from her figures. Because she lumped together the various subspecies of *G. stuarti* under *G. stuarti* s.l. she stated that *G. stuarti* is a characteristic Senonian species and occurs in the Campanian and Maestrichtian of the northwestern Caucasus and various other places in the Soviet Union. She also mentioned that Agalarova (1949) had recorded *G. stuarti* in the Santonian and the Lower Campanian of Azerbaydzhan (Kabristan–Unusdagskaya range). Such forms, most probably belong to *G. stuarti stuartiformis*.

Pessagno (1960 : 89, chart 1, 91, chart 2 and 101 ; 1962 : 354 charts 1, 2, 355 charts 3, 4, and 362) recorded *G. stuarti stuartiformis* as ranging from the late Santonian to the base of the Middle Maestrichtian (base of the *G. gansseri* assemblage subzone) of Puerto Rico.

In the Esna–Idfu region, *G. stuarti stuartiformis* Dalbiez occurs as a common form in the Lower Maestrichtian *G. fornicata* Zone and continues to the basal part of the Middle Maestrichtian *G. gansseri* Zone, where it dies out completely.

Globotruncana stuarti subspinosa (Pessagno)

(Pl. 10, figs. 2*a*–3*c*)

1960 *Globotruncana* (*Globotruncana*) *subspinosa* Pessagno : 101, pl. 1, figs. 1–9, pl. 5, fig. 5.

1962 *Globotruncana* (*Globotruncana*) *stuarti subspinosa* (Pessagno) Pessagno : 362, pl. 2, figs. 7–9.

? 1963. *Globotruncana undulata* Lehmann : 148, pl. 9, figs. 3*a*–*c* ; text-figs. 2*t*, *u*.

Description. (Specimen, Pl. 10, figs. 3*a*–*c*.) Test large, subcircular in outline, umbilico-convex, coiled in a very low trochospire ; dorsal side slightly raised, ventral side strongly protruding ; equatorial periphery nearly circular, weakly lobate to almost entire ; axial periphery strongly acute, with a single, well-developed, pinched-out, faintly beaded keel ; chambers on the dorsal side 23 arranged in 4 dextrally coiled whorls ; the initial chambers are very small, slightly inflated, globigerine ; they increase slowly in size and are followed by crescentic chambers which increase more rapidly in size ; the last whorl is composed of 5½ large chambers, the early ones of which are crescentic, elongated in the direction of coiling and slightly crenulate, while the last three are roughly trapezoidal and relatively much bigger ; on the ventral side the chambers are 5½, large, overlapping, typically stuarti-form, distinctly outlined, strongly inflated around the umbilicus and somewhat steeply sloping towards the pinched-out marginal keel ; sutures on the dorsal side distinct, much thickened and raised, slightly curved and heavily beaded in the early part, straight and limbate later, giving the chambers their roughly quadrangular shape ; on the ventral side the sutures are slightly curved, thickened, raised and beaded ; umbilicus large, roughly hexagonal in outline, relatively deep, surrounded by raised, beaded ridges and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate, except for the imperforate keel and tegilla ; surface generally smooth, with a few small papillae on the early part of the ventral side.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·62 mm.
Minimum diameter = 0·52 mm.
Thickness = 0·31 mm.

MAIN VARIATION.

1. Chambers, 18–24, arranged in 3–4 whorls, generally dextrally coiled (all the specimens studied coiled dextrally).
2. The last whorl is composed of 5–7 large chambers which tend to be roughly trapezoidal in the last part.

REMARKS. Pessagno (1960) described *G. subspinosa* as a new species, but in 1962, he regarded it as a subspecies of *G. stuarti* (de Lapparent). Lehmann (1963) described as *G. undulata* n.sp. from the Santonian of the Tarfaya province, western Morocco, a form which only differs from *G. stuarti subspinosa* in being raised on the dorsal side. This form is doubtfully included in the synonymy of *G. stuarti subspinosa* as it was recorded from slightly older strata.

Globotruncana stuarti subspinosa is distinguished from *G. stuarti stuartiformis* by the trapezoidal shape of its chambers on the dorsal side, and from *G. stuarti stuarti* by its irregular, slightly lobate periphery, the strongly angular shape of its chambers on the dorsal side which are much wider and less elongated in the direction of coiling, and by the less regular rate of growth of its chambers. It is believed to have arisen from *G. stuarti stuartiformis* in the early Campanian and to have evolved into *G. stuarti stuarti* (de Lapparent) in the Upper Campanian or Lower Maestrichtian. The stratigraphical ranges of these three forms favour this proposition.

HYPOTYPES. P.45559.

HORIZON AND LOCALITY. Figured specimens from sample No. 18, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. *G. stuarti subspinosa* was first described from the Parguera limestone and Rio Yauco mudstone formations of Puerto Rico and was shown on Passagno's distribution chart (1960 : 89, chart 1) to be rare in his Lower Campanian *Praeglobotruncana gautierensis* Subzone, common in his Upper Campanian *Rugoglobigerina rugosa–Globotruncana rosetta* Subzone and in his lowermost Maestrichtian *Globotruncana lapparenti lapparenti* Zonule. In 1962 (354–355, charts 1, 2 and 4) he listed *G. stuarti subspinosa* as rare to common in the early Campanian and rare to abundant in the early Maestrichtian.

In the Esna–Idfu region, *G. stuarti subspinosa* is rare to common in the Lower Maestrichtian *G. fornicata* Zone and continues up to the basal part of the Middle Maestrichtian *G. gansseri* Zone, where it dies out completely.

Globotruncana subcircumnodifer Gandolfi

1955 *Globotruncana* (*Rugoglobigerina*) *circumnodifer subcircumnodifer* Gandolfi : 44, pl. 2, figs. 8*a–c*.

? 1955 *Globotruncana* (*Rugoglobigerina*) *pennyi subpennyi* Gandolfi : 73, pl. 7, figs. 7*a–c*.

1956 *Rugotruncana tilevi* Brönnimann & Brown : 547, pl. 22, figs. 1–3.
1956 *Rugotruncana ellisi* Brönnimann & Brown : 547, pl. 22, figs. 7–9.
1960 *Globotruncana* (*Rugotruncana*) *tilevi* (Brönnimann & Brown) ; Pessagno : 102, pl. 5, fig. 10.
1962 *Globotruncana* (*Rugotruncana*) *subcircumnodifer* (Gandolfi) Berggren : 67–69, pl. 10, figs. 4*a*–*c*.

REMARKS. Gandolfi (1955) considered *Globigerina circumnodifer* Finlay to belong to *Rugoglobigerina* which he regarded as a subgenus of *Globotruncana* Cushman, and described the present form as a new subspecies.

Berggren (1962) stated that examination of the holotypes of *G.* (*R*) *circumnodifer* Gandolfi, *G.* (*R*) *pennyi subpennyi* Gandolfi, *R. tilevi* Brönnimann & Brown and *R. ellisi* Brönnimann & Brown proved them all to be junior synonyms of *G.* (*R*) *circumnodifer subcircumnodifer* Gandolfi. He proposed the elevation of this subspecies to specific rank, naming it *Globotruncana* (*Rugotruncana*) *subcircumnodifer* Gandolfi as Finlay's form appears to be a true *Rugoglobigerina*. However, as *Rugotruncana* is a junior synonym of *Globotruncana* Cushman, as mentioned above, the name of the species is here considered as *G. subcircumnodifer* Gandolfi.

HYPOTYPE. P.45560.

HORIZON AND LOCALITY. Hypotype from sample No. 18, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. Gandolfi (1955) recorded this species from the Colon shale of northeastern Colombia, where he considered its range as Campanian (in fact it is most probably Maestrichtian as explained on p. 133).

Brönnimann & Brown described their *R. ellisi* and *R. tilevi*, from the Campanian–Maestrichtian of Texas and Arkansas, and from the Upper Maestrichtian of Habana, Cuba, respectively.

Globotruncana subcircumnodifer was also recorded from the Lower Maestrichtian of Puerto Rico (Pessagno 1960), and from the Lower Maestrichtian of Scandinavia and New Jersey (Berggren 1962).

In the Esna–Idfu region, *G. subcircumnodifer* is recorded as a common form in the Middle Maestrichtian *G. gansseri* Zone, fading out gradually upwards in the section to occur as a rare scattered form in the Upper Maestrichtian *G. esnehensis* Zone, where it dies out completely.

Globotruncana tricarinata colombiana Gandolfi

1955 *Globotruncana tricarinata colombiana* Gandolfi : 20–22, pl. 1, figs. 3*a*–4*c* ; ? text-figs. 5 (1*a*–2*c*), 6 (4*a*, *b*).

REMARKS. *Globotruncana tricarinata colombiana* was first described by Gandolfi (1955) from the Manaure and Colon shale formations of northeastern Colombia. It is believed to have evolved from *G. tricarinata tricarinata* (Quereau) as mentioned by Gandolfi, who also suggested that it evolved into the form he described as " *G. tricarinata colombiana?* ". However, the latter is more closely related to the *G. forni-*

cata group and may belong to *G. fornicata cesarensis* Gandolfi. On the other hand, the morphology and stratigraphical range of *G. tricarinata colombiana* indicate that it is possibly related to both *G. aegyptiaca aegyptiaca* Nakkady and to *G. gagnebini* Tilev, which continue in younger strata above.

Hypotype. P.45561.

Horizon and locality. Hypotype from sample No. 4, Abou Saboun section.

Stratigraphical range. Gandolfi (1955) gave the range of this subspecies as Upper Santonian–Lower Campanian with rare occurrences in the Upper Campanian.

However, as mentioned above, his Campanian may possibly belong to the Maestrichtian.

In the Esna–Idfu region, *G. tricarinata colombiana* is common in the Lower Maestrichtian *G. fornicata* Zone; it decreases gradually in number upwards in the section becoming rare in the lower part of the Middle Maestrichtian *G. gansseri* Zone, where it dies out completely.

Globotruncana tricarinata tricarinata (Quereau)

1893 *Pulvinulina tricarinata* Quereau : 89, pl. 5, figs. 3*a–d*.
1918 *Rosalina linnei* type 2 de Lapparent : 4, pl. 1, fig. 1, text-figs. 1*b*, *d–f*; 5, 2*d*, *n*.
1941 *Globotruncana linnei tricarinata* (Quereau) Vogler : 287, pl. 33, figs. 22–31.
1942 *Globotruncana linnei* (d'Orbigny) ; Gandolfi, pl. 10, fig. 7.
1945 *Globotruncana lapparenti tricarinata* (Quereau) ; Bolli : 232, pl. 9, fig. 13, text-figs. 1 (19, 20).
1946 *Globotruncana canaliculata* (Reuss) ; Cushman (pars) : p. 149, pl. 61, figs. 18*a–c*, non figs. 17*a–c*.
1951 *Globotruncana lapparenti tricarinata* (Quereau), Tilev : 79–86, text-figs. 24*a–d*. (See also Tilev 1952 where figures are repeated.)
1953 *Globotruncana lapparenti* Brotzen ; Subbotina (pars) : 178, pl. 7, figs. 3*a*–4*c* ; ? pl. 6, figs. 5*a*–6*c* ; ? pl. 7, figs. 1*a*–2*c*, 5*a–c*.
1960 *Globotruncana lapparenti lapparenti* Brotzen, Vinogradov : 313, pl. 2, figs. 8*a–c*.

Remarks. *Globotruncana tricarinata tricarinata* was first described, from thin sections only, by Quereau (1893). The morphological characters and stratigraphical distribution of the species were later much confused, and its interpretation by different authors varied considerably.

Gandolfi (1955) described *G. tricarinata colombiana* as a new subspecies and thus Quereau's form is here designated as nominate subspecies.

As can be seen from Quereau's original description and figures, the species is mainly characterized by the umbilical flange which is so well developed that in side view or in thin section, it appears as a third carina beside the two well-developed marginal keels ; hence its name. However, various forms showing the same character, but differing in the shape of test and in the number and shape of chambers were figured by subsequent authors.

Until isolated specimens from the type section of Quereau are carefully examined, it is not possible to decide which of these forms is *G. tricarinata tricarinata* (Quereau).

The few specimens recorded from the Esna–Idfu region show clearly the two well-developed marginal keels and the strongly protruding umbilical flange characteristic of Quereau's form. They also conform well with the figures given by Tilev (1951, 1952) whose thin section is almost identical with that of Quereau. However, they differ from the forms figured by Cita (1948), Noth (1951), Said & Kenawy (1956) and Berggren (1962). The form figured by Barr (1962) as *G. linneiana tricarinata* (Quereau) may possibly belong to *G. tricarinata colombiana* Gandolfi.

Globotruncana tricarinata tricarinata is believed to have evolved from *G. linneiana linneiana* (d'Orbigny) into *G. arca* (Cushman) as previously suggested by various authors (e.g. Vogler 1941, Gandolfi 1955, Brönnimann & Brown 1956 and Berggren 1962).

HYPOTYPE. P.45562.

HORIZON AND LOCALITY. Hypotype from sample No. 3, Abou Saboun section.

STRATIGRAPHICAL RANGE. *Globotruncana tricarinata tricarinata* was first described from the Campanian–Maestrichtian of Switzerland and was recorded from the same level in various parts of the world.

In the Esna–Idfu region *G. tricarinata tricarinata* is common in the Lower Maestrichtian *G. fornicata* Zone, decreasing gradually upwards in the section to die out completely before the basal part of the overlying *G. gansseri* Zone.

Globotruncana ventricosa White

1928*b* *Globotruncana canaliculata* (Reuss) var. *ventricosa* White : 284, pl. 38, figs. 5*a–c*.
? 1954 *Globotruncana ventricosa* White ; Nakkady & Osman : 90–91, pl. 19, figs. 9*a–c*.
1955 *Globotruncana ventricosa carinata* Dalbiez : 171, text-figs. 8*a–d*.
1957*a* *Globotruncana ventricosa* White ; Bolli : 57, pl. 13, figs. 4*a–c*.

REMARKS. Brotzen (1936) raised White's variety to specific rank although his figures are completely different from those of White. The form described by Sigal (1952) as *G. lamellosa*, from the Lower Maestrichtian of Algeria, appears from his figures to be closely related to *G. ventricosa* White. However, examination of the type specimens of *G. lamellosa* Sigal showed that the latter species is distinguished by its unequally biconvex test, with a more protruding ventral side ; highly lobate periphery ; two closely spaced keels, reduced to a single keel on the last few chambers or chamber ; a well developed umbilical flange ; curved, raised, beaded dorsal sutures and radial, depressed ventral ones ; and its very wide umbilicus.

Dalbiez (1955) described two new subspecies of *G. ventricosa* White which he named *G. ventricosa carinata* and *G. ventricosa primitiva* respectively, and thus he changed the name of the present species to *G. ventricosa ventricosa* White. However, examination of the type specimens of these forms in Dr. Dalbiez's collection showed that his *G. ventricosa ventricosa* White is actually *G. concavata* Brotzen, and that although the figures were published under the first name, the slide carried the name *G. ventricosa concavata* (Brotzen). Again, the holotype of *G. ventricosa carinata* Dalbiez was found to differ from *G. ventricosa* White only in having a slightly wider umbilicus and a more developed umbilical flange. Variation in such characters is well known in populations of *G. ventricosa* White and is not considered of any taxonomic importance. Thus *G. ventricosa carinata* Dalbiez is considered a junior synonym of *G. ventricosa* White. Similarly, the holotype of *G. ventricosa primitiva* Dalbiez, although not well preserved, is identical with *G. concavata* (Brotzen) of which it is here considered a junior synonym.

Globotruncana ventricosa White was also confused with *G. gagnebini* Tilev (e.g. Bolli 1951, Gandolfi 1955, etc.) and with *G. tricarinata* (Quereau) (e.g. Mornod 1950). It has possibly evolved from *G. tricarinata tricarinata* (Quereau) and into *G. gagnebini* Tilev, although Gandolfi (1955) suggested its evolution from *G. tricarinata colombiana*.

HYPOTYPE. P.45563.

HORIZON AND LOCALITY. Hypotype from sample No. 16, W. El-Shasawna section.

STRATIGRAPHICAL RANGE. White (1928) described this species from the Campanian, Papagallos shale of Mexico, and Bolli (1957*a*) restricted its range to his *Globotruncana stuarti* Zone which he considered as Upper Campanian. It was also recorded from the Campanian–Maestrichtian of southwestern Sinai, Egypt (Nakkady & Osman 1952) and from the Upper Santonian of Tunisia (Dalbiez 1955).

In the Esna–Idfu region, *G. ventricosa* is rare in the Lower Maestrichtian *G. fornicata* Zone and in the lower part of the Middle Maestrichtian *G. gansseri* Zone, where a great number of transitional stages occur between it and *G. gagnebini* (e.g. Pl. 2, figs. 3*a*–*d*).

Globotruncana youssefi sp. nov.

(Pl. 6, figs. 4*a*–*d*)

DIAGNOSIS. A *Globotruncana* with large, subcircular, strongly umbilico-convex test; distinctly lobate periphery; entire single keel; globigerine early part and crescentic later chambers; strongly curved, raised beaded dorsal sutures; peculiarly shaped last chamber slightly tilted towards the umbilicus, surface rough.

DESCRIPTION. Test large, planoconvex, umbilico-convex, coiled in a low trochospire ; dorsal side almost flat and weakly imbricate, with the last chambers slightly lower than the early ones; ventral side strongly inflated and very distinctly protruding ; equatorial periphery subcircular, distinctly lobate with a single, well-developed, much thickened and beaded marginal keel ; axial periphery subangular ; chambers on the dorsal side 19, arranged in 3 dextrally coiled whorls ; the initial chambers are very small, globular and inflated ; they increase slowly in size, and are followed by relatively larger, globular, weakly inflated chambers which tend to be slightly elongated in the direction of coiling ; the last whorl is composed of $5\frac{1}{2}$ large, crescentic chambers which increase slowly in size, except for the last which has a peculiar angular shape that makes it appear slightly smaller than the penultimate ; on the ventral side the chambers are $5\frac{1}{2}$, large, angular conical, strongly inflated and distinctly protruding ; sutures on the dorsal side short, radial, depressed in the early part, distinctly curved, raised and beaded in the later part, although the beading

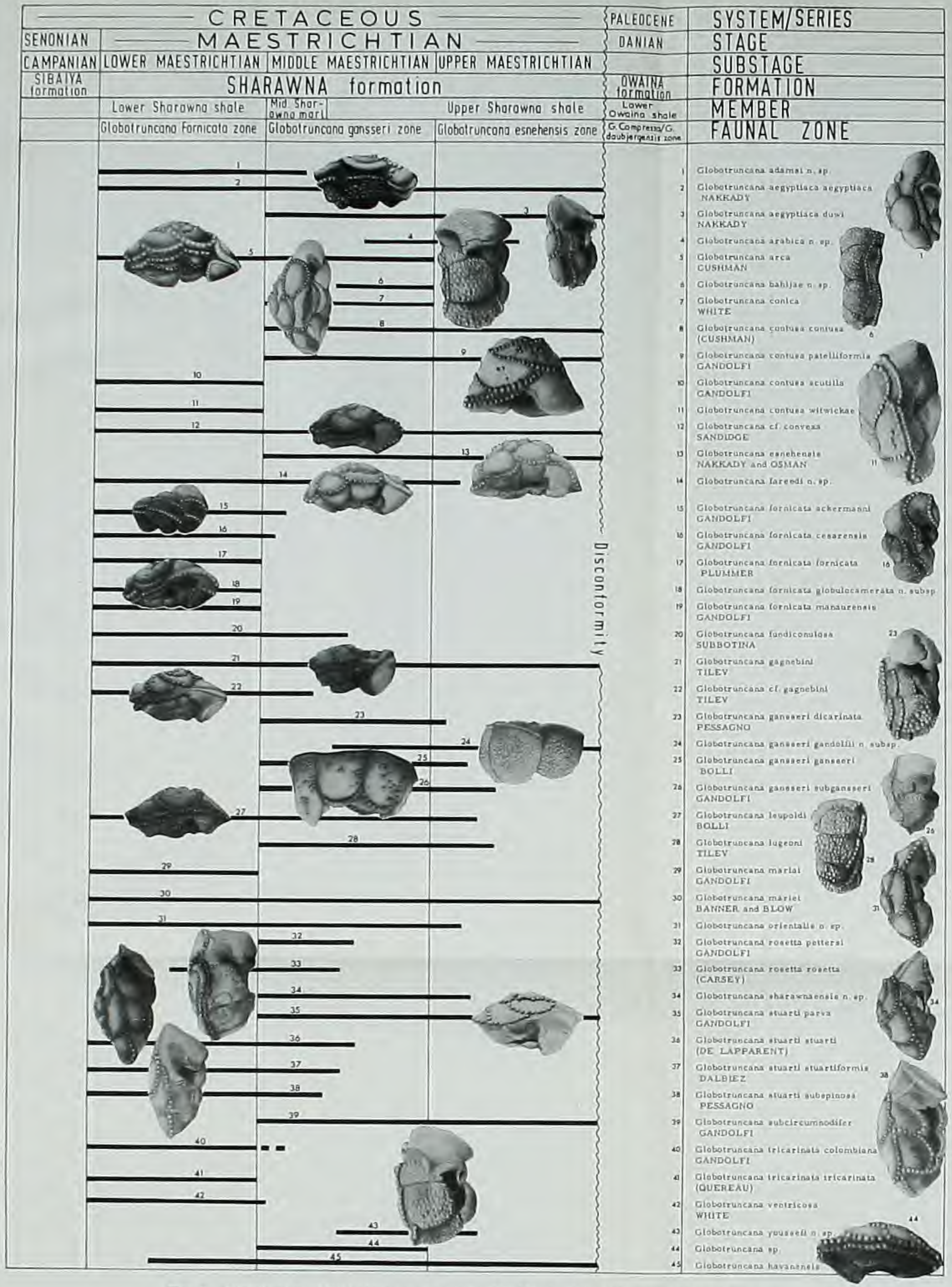


FIG. 9. Distribution of Globotruncana species in the Maestrichtian Sharawna Shale formation.

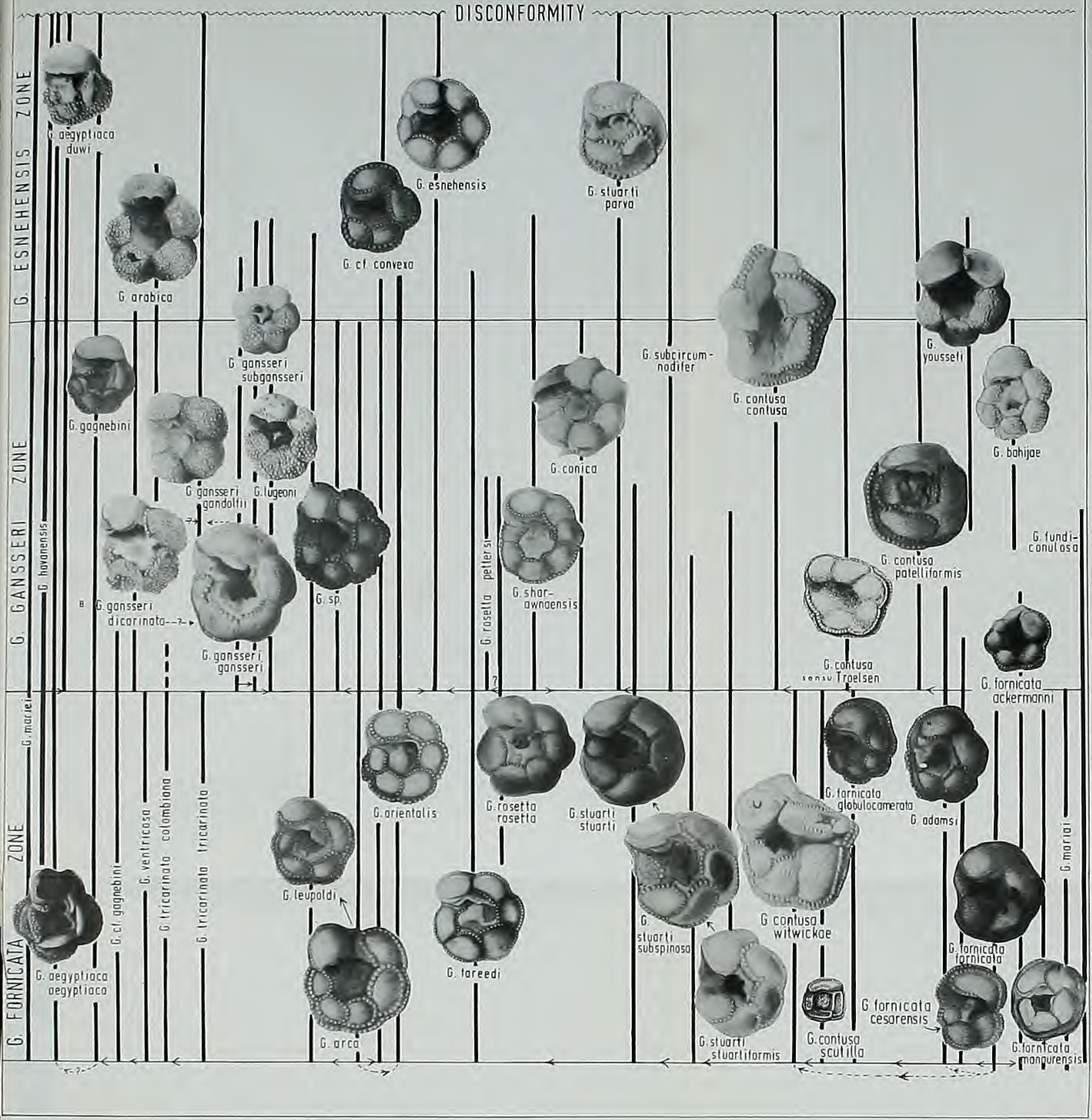


FIG. 10. Suggested Phylogeny of the Globotruncana species in the Maestrichtian Sharawna Shale of the Esna-Idfu Region.

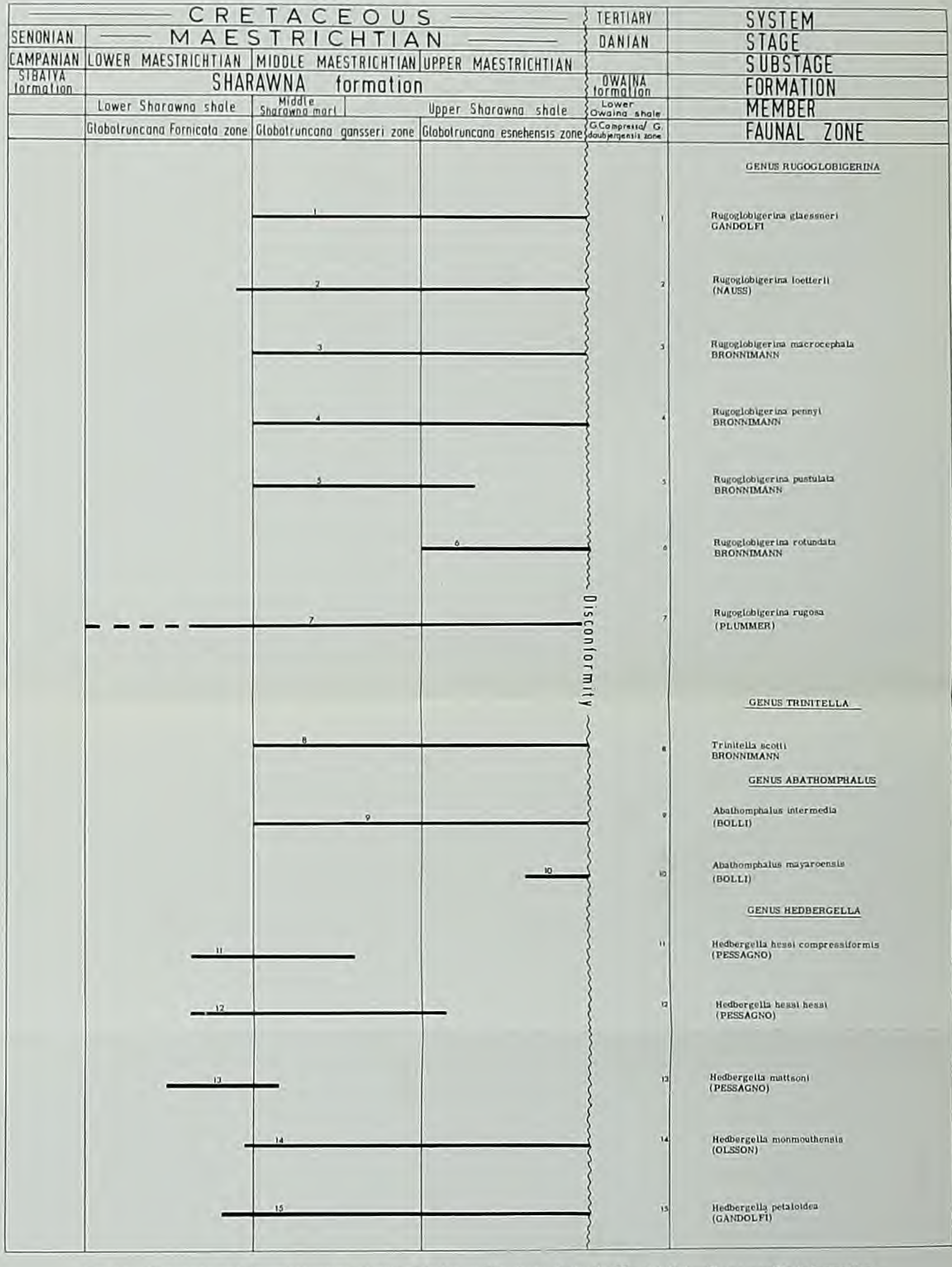


FIG. 11. Distribution of Rugoglobigerina, Abathomphalus and Hedbergella in the Maestrichtian Sharawna Shale formation.

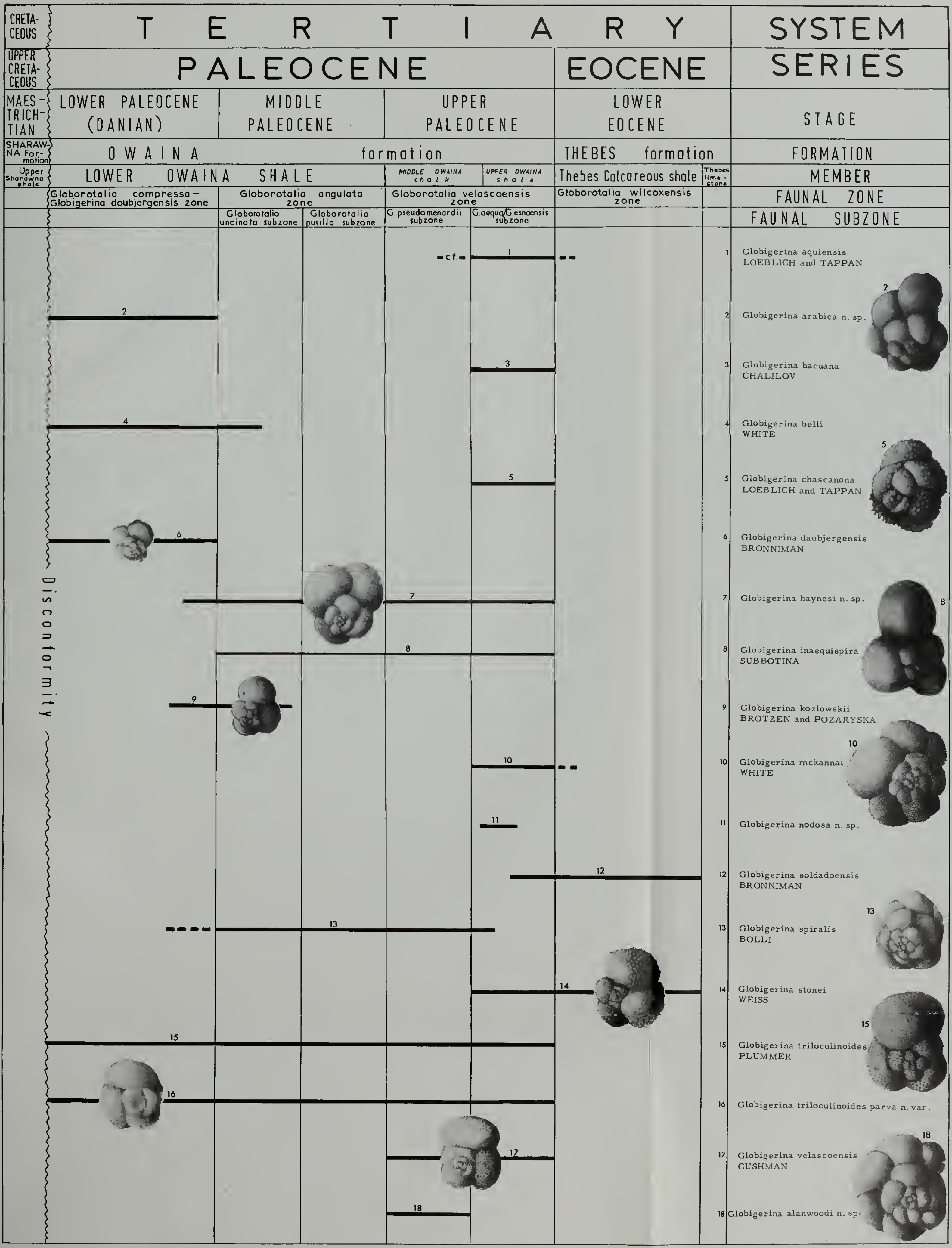


FIG. 12. Distribution of Globigerina species in the Paleocene–Lower Eocene Owaina and Thebes formations.

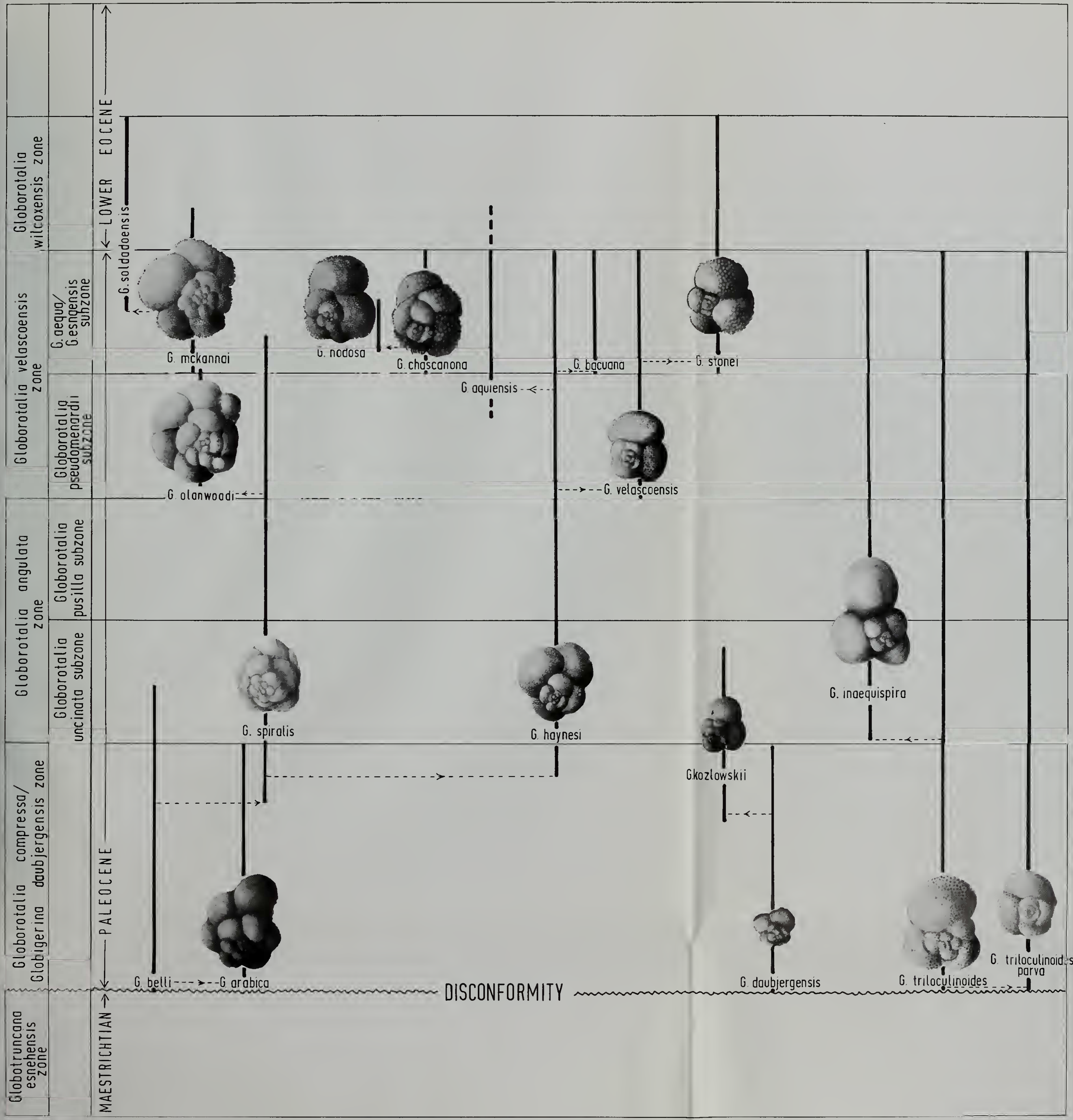


FIG. 13. Suggested Phylogeny of the Globigerina species in the Paleocene–Lower Eocene Owaina and Thebes formations of the Esna-Idfu Region.

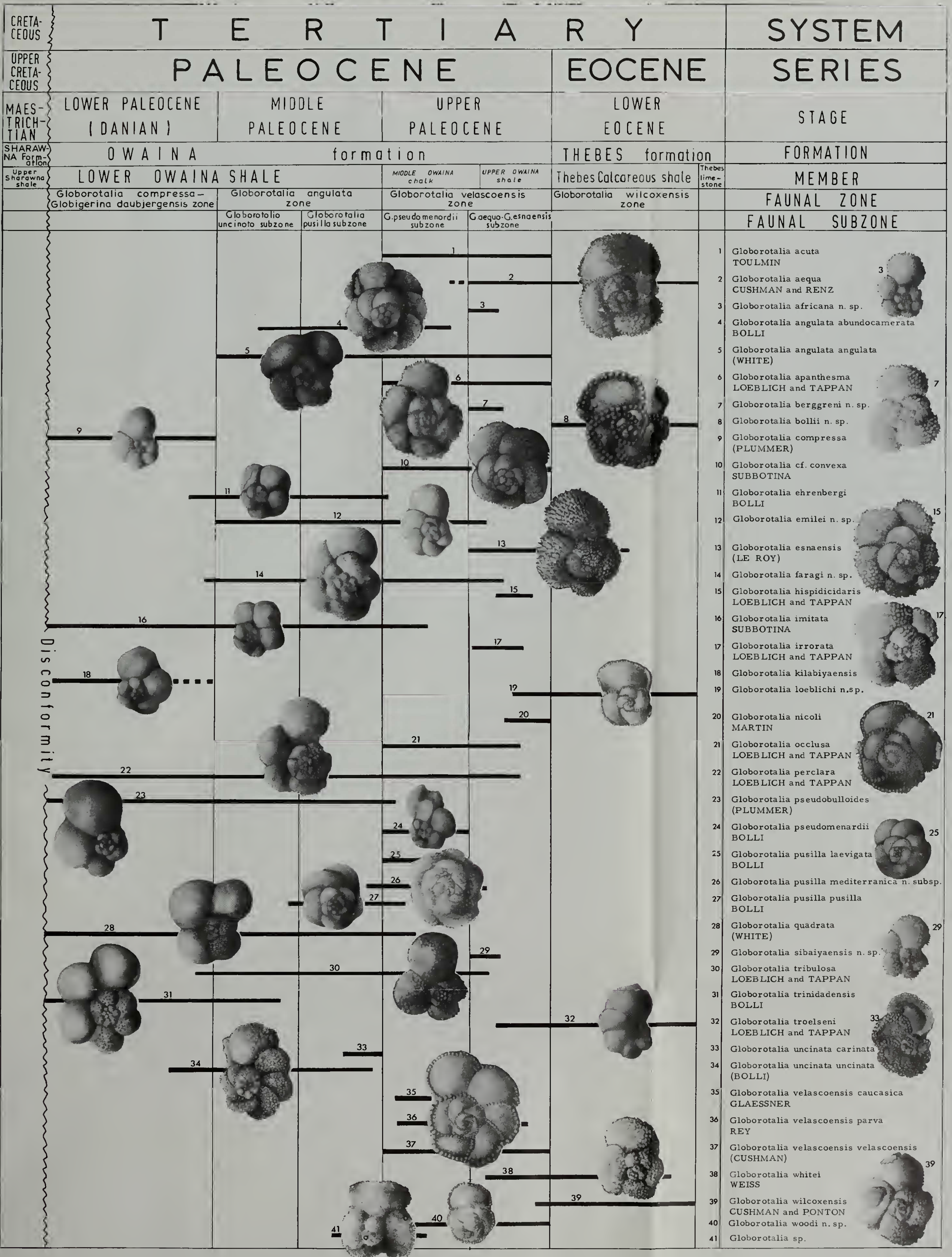


FIG. 14. Distribution of Globorotalia species in the Paleocene–Lower Eocene Owaina and Thebes formations.

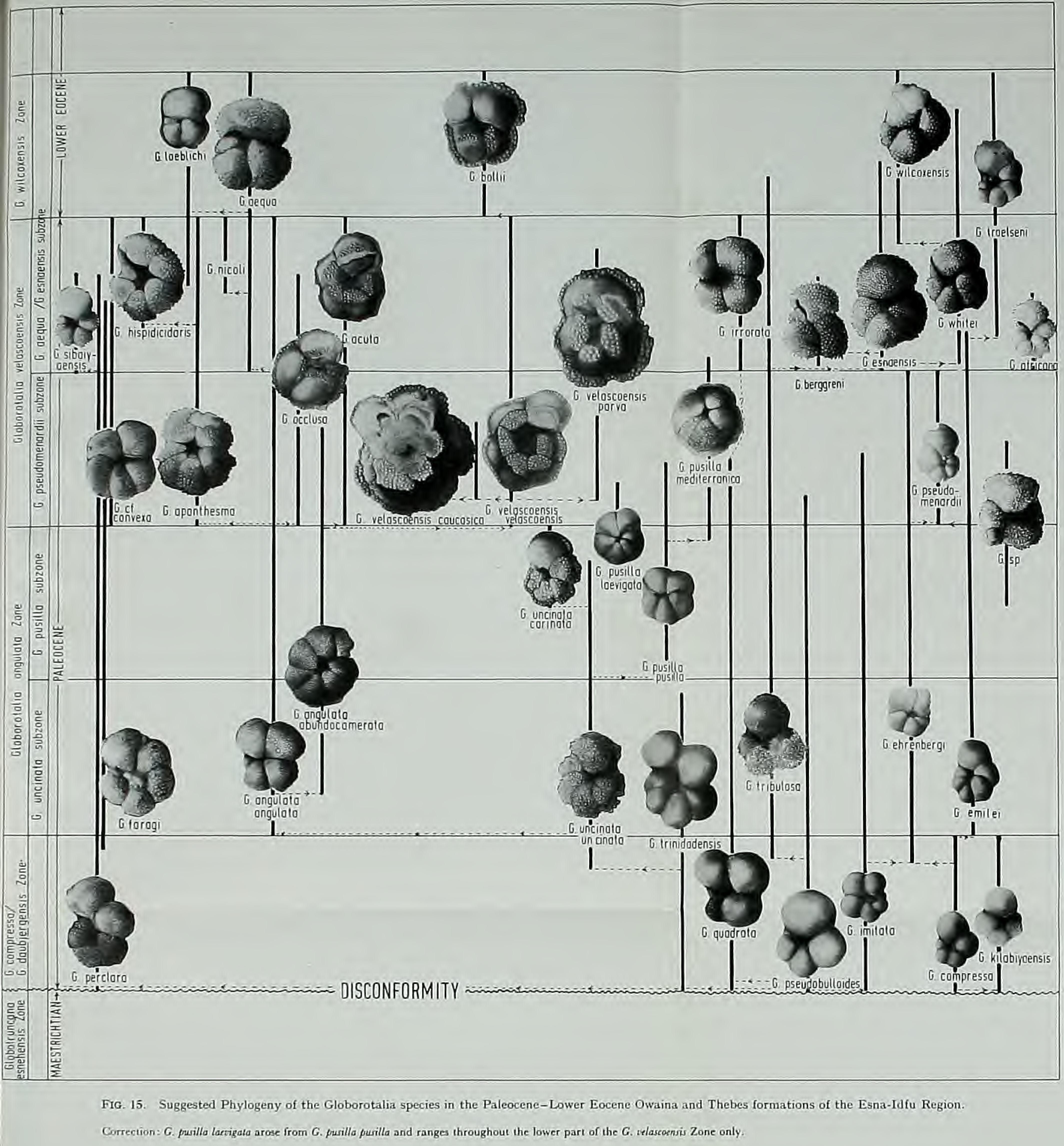


FIG. 15. Suggested Phylogeny of the Globorotalia species in the Paleocene–Lower Eocene Owaina and Thebes formations of the Esna-Idfu Region.

Correction: *G. pusilla laevigata* arose from *G. pusilla pusilla* and ranges throughout the lower part of the *G. velascoensis* Zone only.

fades towards the inner whorl ; on the ventral side the sutures are straight, radial and strongly depressed ; umbilicus pentagonal in outline, wide, deep and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures, only poorly preserved ; wall calcareous, perforate except for the imperforate keel and tegilla ; surface rough in the early part, heavily papillose or even nodose with the papillae decreasing gradually towards the last chamber.

DIMENSIONS OF HOLOTYPE.

Maximum diameter	=	0·54 mm.
Minimum diameter	=	0·43 mm.
Thickness	=	0·31 mm. (of last chamber)

MAIN VARIATION.

1. Chambers 11–21, arranged in 2–3 whorls which are generally dextrally coiled.
2. Chambers in the last whorl 4–6, most commonly 5.

REMARKS. *Globotruncana youssefi* sp. nov. is morphologically similar to both *G. lugeoni* var. *angulata* Tilev and *G. arabica* sp. nov. It is distinguished from the former by its typically crescentic chambers throughout, peculiarly shaped last chamber, strongly curved, raised, beaded dorsal sutures and more strongly developed marginal keel. It differs from *G. arabica* by its almost flat to slightly raised dorsal side, its longer, more curved, raised and beaded dorsal sutures and its perfectly marginal keel.

This species is named after Professor M. I. Youssef, of the Department of Geology, Ain Shams University, Cairo.

HOLOTYPE. P.45564.

PARATYPES. P.45565.

HORIZON AND LOCALITY. Holo- and paratypes, from sample No. 16, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globotruncana youssefi* sp. nov. appears in the upper part of the Middle Maestrichticn *G. gansseri* Zone. It increases upwards in the section to flood the uppermost part of this zone and the lower part of the overlying *G. esnehensis* Zone where it dies out completely.

Globotruncana sp.

(Pl. 1, figs, 6*a*–*c*)

DESCRIPTION. Test large, weakly biconvex, coiled in a slightly high trochospire ; dorsal side broadly arched, ventral side slightly inflated ; equatorial periphery subcircular, distinctly lobate, with two well-developed, beaded keels reduced to one on the last chamber ; axial periphery truncate ; chambers on the dorsal side 21, arranged in 3 dextrally coiled whorls ; they increase slowly and regularly in size ; initial chambers very small, subglobular, weakly inflated, and followed by subcircular to crescentic flattened chambers ; the last whorl is composed of 6½ large, crescentic to petaloid, flattened, or even slightly depressed chambers ; on the ventral side the chambers are 6½, large, subcircular to ovoid, weakly inflated and slightly overlapping ; sutures on the dorsal side curved, raised, thickened and heavily beaded ; on the ventral side they are slightly curved forward, depressed and beaded ; umbilicus polygonal in outline, relatively wide, deep, surrounded by slightly raised, beaded ridges and covered by complex tegilla of which remnants are still preserved ; primary apertures interiomarginal, umbilical ; tegilla with accessory apertures only poorly preserved ; wall calcareous, perforate, except for the imperforate keels and tegilla ; surface delicately papillose on the dorsal side, coarsely papillose on the ventral.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter	=	0·51 mm.
Minimum diameter	=	0·44 mm.
Thickness	=	0·25 mm.

REMARKS. Although the present form is clearly distinguished from the known *Globotruncana* species, it was decided not to name it for the time being because of its rarity. It is morphologically similar to *G. arca* (Cushman), from which it is distinguished by its more compressed test, papillose surface, depressed ventral sutures and single keel on the last chamber. It may have evolved from *G. arca* (Cushman) as suggested by their morphological features and stratigraphical distribution, although no direct evidence was recorded.

MATERIAL. P.45566.

HORIZON AND LOCALITY. Figured specimen from sample No. 20, W. El-Sharawna section.

STRATIGRAPHICAL RANGE. The present species is rare in the Middle Maestrichtian *G. gansseri* Zone.

Genus ***RUGOGLOBIGERINA*** Brönnimann 1952

TYPE SPECIES. *Globigerina rugosa* Plummer 1926.

1952 *Rugoglobigerina* Brönnimann : 16 (Type species : *Globigerina rugosa* Plummer 1926).
1956 *Kuglerina* Brönnimann & Brown : 557 (Type species : *Rugoglobigerina rugosa rotundata* Brönnimann 1952).

Rugoglobigerina glaessneri Gandolfi

1955 *Globotruncana* (*Rugoglobigerina*) *glaessneri glaessneri* Gandolfi ; 50, pl. 3, figs. 10*a–c*.

REMARKS. *Rugoglobigerina glaessneri* is common in both the Middle and Upper Maestrichtian (*G. gansseri* and *G. esnehensis* Zones) of the sections studied. The species was originally described from the Colon shale of northeastern Colombia which was regarded by Gandolfi (1955) as of Campanian–Maestrichtian age, but is most probably of Maestrichtian age only. The form described by Gandolfi as *G.* (*R.*) *glaessneri subglaessneri* is probably a *Globotruncana* not a *Rugoglobigerina*.

HYPOTYPE. P.45649.

HORIZON AND LOCALITY. Hypotype from sample No. 21, W. El-Sharawna section.

Rugoglobigerina loetterli (Nauss)

1947 *Globigerina loetterli* Nauss: 336, pl. 49, figs. 11*a–c*.
1955 *Globotruncana* (*Rugoglobigerina*) *loetterli loetterli* (Nauss): Gandolfi: 35, pl. 1, figs. 15*a–c*.
1955 *Globotruncana* (*Rugoglobigerina*) *loetterli subloetterli* Gandolfi: 36, pl. 1, figs. 14*a–c*.

REMARKS. A few specimens of *R. loetterli* (Nauss) have been recorded from the top part of the Lower Maestrichtian throughout the Middle and Upper Maestrichtian of the Esna–Idfu region. The species was originally described by Nauss (1947) from the late Cretaceous Lloydminster shale of Alberta, Canada, and was recorded by Gandolfi (1955) from the Maestrichtian, Colon shale of northeastern Colombia. The form described by Gandolfi as *G.* (*R.*) *loetterli subloetterli* is here questionably included in the present species, which occasionally shows an arrangement of surface rugosity in the form of weakly developed pseudo-keels.

HYPOTYPE. P.45650.

HORIZON AND LOCALITY. Hypotype from sample No. 16, W. El-Sharawna section.

Rugoglobigerina macrocephala Brönnimann

1952 *Rugoglobigerina* (*Rugoglobigerina*) *macrocephala macrocephala* Brönnimann : 25, pl. 2, figs. 1–3, text-figs. 9*a–s*.
1952 *Rugoglobigerina* (*Rugoglobigerina*) *macrocephala ornata* Brönnimann : 27, pl. 2, figs. 4–6, text-figs. 10*a–i*.
1955 *Globotruncana* (*Rugoglobigerina*) *macrocephala macrocephala* (Brönnimann) ; Gandolfi : 45, pl. 2, figs. 12*a–c*.
1962 *Rugoglobigerina macrocephala* Brönnimann ; Berggren : 76–78, pl. 12, figs. 4*a–c*, text-figs. 9 (1*a*–4*c*), 10 (1–5*s*).

REMARKS. *Rugoglobigerina macrocephala* floods the Middle and Upper Maestrichtian of the sections studied. The species was originally described from the Upper Maestrichtian of Trinidad (Brönnimann 1952) and was later recorded from the Maestrichtain of northeastern Colombia (Gandolfi 1955) and of Denmark (Berggren 1962). *Rugoglobigerina* (*R*) *macrocephala ornata* Brönnimann is a junior synonym of the present species and so is probably *G.* (*R.*) *ornata ornata* (Brönnimann) of Gandolfi (1955). On the other hand, both *G.* (*R.*) *macrocephala submacrocephala* Gandolfi 1955 and *G.* (*R.*) *ornata subornata* Gandolfi 1955, possibly belong to the genus *Globotruncana*, not *Rugoglobigerina*.

HYPOTYPE. P.45651.

HORIZON AND LOCALITY. Hypotype from sample No. 16, W. El-Sharawna section.

Rugoglobigerina pennyi Brönnimann

1952 *Rugoglobigerina* (*Rugoglobigerina*) *rugosa* (Plummer) subsp. *pennyi* Bronnimann: 34–35, pl. 4, figs. 1–3, text-figs. 14*a*–*i*.
1955 *Globotruncana* (*Rugoglobigerina*) *pennyi pennyi* (Brönnimann) ; Gandolfi : 73, pl. 7, figs. 8*a*–*c*.
1957 *Rugoglobigerina rugosa* (Plummer) ; Edgell : 115, pl. 4, figs. 10–12.
1962 *Rugoglobigerina pennyi* Brönnimann ; Berggren : 75, pl. 12, figs. 1*a*–3*c*.

REMARKS. *Rugoglobigerina pennyi* is common in the Middle and Upper Maestrichtian of the sections studied. The species was originally described from the Upper Maestrichtian of Trinidad (Brönnimann 1952) and was later recorded from the Maestrichtian of northeastern Colombia (Gandolfi 1955), of northwestern Australia (Edgell 1957), and of Scandinavia (Berggren 1962).

HYPOTYPE. P.45652.

HORIZON AND LOCALITY. Hypotype from sample No. 18, W. El-Sharawna section.

Rugoglobigerina pustulata Brönnimann

1952 *Rugoglobigerina* (*Rugoglobigerina*) *reicheli pustulata* Brönnimann : 20, pl. 2, figs. 7–9 ; text-figs. 6*a*–*m*, 7*a*–*i*.
1960 *Rugoglobigerina reicheli pustulata* Brönnimann ; Olsson : 50, pl. 10, figs. 13–15.
1962 *Rugoglobigerina pustulata* Brönnimann ; Berggren : 78–80, pl. 13, figs. 1*a*–*c* ; text-fig. 10 (6–12).

REMARKS. *Rugoglobigerina pustulata* is common throughout the Middle and Upper Maestrichtian of the sections studied. The species was originally described from the Upper Maestrichtian of Trinidad, and was later recorded from the Maestrichtian of New Jersey, U.S.A. (Olsson 1960) and from the Upper Maestrichtian of Denmark (Berggren 1962).

HYPOTYPE. P.45653.

HORIZON AND LOCALITY. Hypotype from sample No. 18, W. El-Sharawna section.

Rugoglobigerina rotundata Brönnimann

1952 *Rugoglobigerina* (*Rugoglobigerina*) *rugosa* (Plummer) subsp. *rotundata* Brönnimann : 34, pl. 4, figs. 7–9 ; text-figs. 15*a*–16*c*.
1955 *Globotruncana* (*Rugoglobigerina*) *rotundata rotundata* (Brönnimann) ; Gandolfi : 70, pl. 7, figs. 2*a*–*c*.

REMARKS. A few specimens of *R. rotunda* have been recorded from the Upper Maestrichtian of the sections studied. In the G. Owaina section, rare specimens were also recorded in the Upper part of the Middle Maestrichtian. The species was originally described from the Upper Maestrichtian of Trinidad, and was recorded from the Maestrichtian of northeastern Colombia (Gandolfi 1955) and as *R.* cf. *rotundata* from the Upper Maestrichtian of Denmark (Berggren 1962). Brönnimann & Brown (1956) made the present species the type of their monotypic genus *Kugleri-*

na, which was said to differ from *Rugoglobigerina* in being more highly spired, having a smaller and deeper umbilicus, and in having short apertural flaps which extend into the umbilicus, but do not form a cover-plate. However, as the cover-plate is a delicate structure which is rarely well preserved, and as the other characters are of specific rather than generic importance, *Kuglerina* Brönnimann & Brown 1956 is considered a junior synonym of *Rugoglobigerina* Brönnimann 1952.

HYPOTYPE. P.45654.

HORIZON AND LOCALITY. Hypotype from sample No. 23, W. El-Sharawna section.

Rugoglobigerina rugosa (Plummer)

1926 *Globigerina rugosa* Plummer : 38, pl. 2, figs. 10*a–d*.

1932 *Globigerina rugosa* Plummer ; Sandidge : 367, pl. 33, figs. 11, 12.

1952 *Rugoglobigerina* (*Rugoglobigerina*) *rugosa rugosa* (Plummer) Brönnimann : 28, text-figs. 11*a*–13*i*.

1955 *Globotruncana* (*Rugoglobigerina*) *rugosa rugosa* (Plummer) ; Gandolfi : 72, pl. 7, figs. 6*a–c* ; text-fig. 11*c*.

1957 *Rugoglobigerina rugosa* (Plummer) ; Bolli, Loeblich & Tappan : 42, pl. 11, figs. 2*a–c*.

1960 *Rugoglobigerina rugosa rugosa* (Plummer) ; Olsson : 50, pl. 10, figs. 16–18.

1962 *Rugoglobigerina rugosa* (Plummer) ; Berggren : 71–75 ; pl. 11, figs. 1*a*–5*b* ; text-fig. 8 (1*a*–5*b*).

REMARKS. This species occurs throughout the Maestrichtian part of the sections studied, being rare at the base and increasing gradually in number towards the top, where it floods the Middle and Upper Maestrichtian. It was originally described from the Maestrichtian Upper Navarro formation of Texas, and was later recorded from the same formation (Bolli, Loeblich & Tappan 1957), from the Maestrichtian of Alabama (Sandidge 1932), of Trinidad (Brönnimann 1952), of northeastern Colombia (Gandolfi 1955), of New Jersey (Olsson 1960) and of Scandinavia (Berggren 1962).

HYPOTYPE. P.45655.

HORIZON AND LOCALITY. Hypotype from sample No. 18, W. El-Sharawna section.

Genus ***TRINITELLA*** Brönnimann 1952

TYPE SPECIES. *Trinitella scotti* Brönnimann 1952.

1952 *Trinitella* Brönnimann : 56 (Type species : *Trinitella scotti* Brönnimann 1952).

REMARKS. *Trinitella* Brönnimann 1952 is morphologically transitional between *Globotruncana* Cushman 1927 and *Rugoglobigerina* Brönnimann 1952. It is distinguished from the former by the lack of an entire keel or keels and an imperforate peripheral band, and from the latter by its compressed last chamber or chambers and partially developed keel. The fact that this genus is monotypic, may suggest its inclusion in either *Rugoglobigerina* (to which it is more closely related) or *Globotruncana*. However, as it does not conform to the present definition of either of these genera, it is best treated separately until further study can reveal its true position.

Trinitella scotti Brönnimann

1952 *Trinitella scotti* Brönnimann : 57, pl. 4, figs. 4–6 ; text-figs. 30*a–m*.
1956 *Trinitella scotti* Brönnimann ; Brönnimann & Brown : 555, pl. 23, figs. 13–15.
1957 *Rugoglobigerina scotti* (Brönnimann) Bolli, Loeblich & Tappan : 43, pl. 11, figs. 3*a*–4*c*.

REMARKS. *Trinitella scotti* has been recorded from the Middle and Upper Maestrichtian of the studied sections (the *G. gansseri* and the *G. esnehensis* Zones). It is generally rare at the base of the Middle Maestrichtian, but gradually increases in number upwards in the section becoming common to abundant. The species was originally described from the Maestrichtian of Trinidad and was later recorded from the Maestrichtian of Texas, Arkansas, Alabama, Puerto Rico and Cuba (Brönnimann & Brown 1956) and from that of Trinidad and Texas (Bolli, Loeblich & Tappan 1957).

HYPOTYPE. P.45656.

HORIZON AND LOCALITY. Hypotype from sample No. 19, W. El-Sharawna section.

Family **ROTALIPORIDAE** Sigal 1958

Subfamily **HEDBERGELLINAE** Loeblich & Tappen 1961

Genus ***HEDBERGELLA*** Brönnimann & Brown 1958

TYPE SPECIES. *Anomalina lorneiana* d'Orbigny var. *trocoidea* Gandolfi 1942.

REMARKS. The genus *Hedbergella* as defined by Brönnimann & Brown (1958) and emended by Loeblich & Tappan (1961, 1964) only differs from *Praeglobotruncana* Bermudez 1952, in lacking a keel or a poreless margin, and thus was included as a subgenus of the latter by Banner & Blow (1959). However, the two forms are here treated separately, although further study may prove the non-carinate forms to have evolved imperceptibly into the carinate ones, as is the case in the genus *Globorotalia* Cushman 1927 (see below). This may be substantiated by the fact that the keel in *Praeglobotruncana* is generally weakly developed and that forms of *Hedbergella* with pseudo-keel and/or a pinched out periphery have been recorded. Again, the general tendency towards the development of more flattened chambers (characteristic of *Praeglobotruncana*) from the globular ones (characteristic of *Hedbergella*) are also documented. However, as only the youngest representatives of this genus are recorded in the present study, no firm conclusion regarding their ancestry could be reached. The classification proposed by Loeblich & Tappan (1961, 1964) has therefore been temporarily accepted.

Hedbergella hessi compressiformis (Pessagno)

1962 *Praeglobotruncana hessi compressiformis* Pessagno : 360, pl. 5, figs. 1–7.

REMARKS. *Hedbergella hessi compressiformis* is rare in the upper part of the Lower Maestrichtian and in most of the Middle Maestrichtian of the sections studied. The species was originally described from the Maestrichtian Rio Yauco formation of Puerto Rico.

HYPOTYPE. P.45661.

HORIZON AND LOCALITY. Hypotype from sample No. 16, Gebel Owaina section.

Hedbergella hessi hessi (Pessagno)

1962 *Praeglobotruncana hessi hessi* Pessagno : 358, pl. 5, figs. 8–12.

REMARKS. A few specimens of *Hedbergella hessi hessi* are recorded from the upper part of the Lower Maestrichtian (*G. fornicata* Zone) of the sections studied. It continues as a rare form up to the basal part of the Upper Maestrichtian (*G. esnehensis* Zone) where it dies out completely. The species was originally described from the Maestrichtian Rio Yauco formation of Puerto Rico.

HYPOTYPE. P.45662.

HORIZON AND LOCALITY. Hypotype from sample No. 16, Gebel Owaina section.

Hedbergella mattsoni (Pessagno)

1960 *Praeglobotruncana mattsoni* Pessagno : 98, pl. 2, figs. 1–3, 6–8.
1962 *Praeglobotruncana mattsoni* Pessagno ; Pessagno : 358, pl. 5, figs. 14–16.

REMARKS. *Hedbergella mattsoni* is rare in the Lower Maestrichtian and in the base of the Middle Maestrichtian of the sections studied. It was originally described from the Maestrichtian Rio Yauco formation of Puerto Rico.

HYPOTYPE. P.45663.

HORIZON AND LOCALITY. Hypotype from sample No. 20, Wadi El-Sharawna section.

Hedbergella monmouthensis (Olsson)

1960 *Globorotalia monmouthensis* Olsson : 47, pl. 9, figs. 22–24.
1962 *Praeglobotruncana* (*Hedbergella*) *monmouthensis* (Olsson) Berggren : 37–41, pl. 8, figs. 1*a*–3*c* ; text-figs. 4 (1*a*–5*c*).

REMARKS. *Hedbergella monmouthensis* appears in the uppermost part of the Lower Maestrichtian (*G. fornicata* Zone) of the sections studied. It increases gradually in numbers upwards in the section, becoming common in both the Middle and Upper Maestrichtian (the *G. gansseri* and the *G. esnehensis* Zones) ; it dies out completely just below the conglomerate separating the Maestrichtian from the overlying Danian. The species was first described as *Globorotalia monmouthensis* by Olsson (1960), from the Maestrichtian Redbank formation of New Jersey, but the well developed umbilical portici clearly distinguish it from *Globorotalia* and justify its position in *Hedbergella*. The species was also recorded from the Upper Maestrichtian of Scandinavia (Berggren 1962) and from the Maestrichtian of Belgium, Holland and Scandinavia (Hofker 1956*a*, 1957*a*, 1958*a*, 1959*e*, 1960*a*, 1960*d*, 1960*i*), where the latter author confused it with *Globorotalia pseudobulloides* (Plummer), *G. compressa* (Plummer), *G. quadrata* White, and *Globigerina linaperta* Finlay. Similarly, most records of

Globorotalia and *Globigerina* species from Maestrichtian strata, probably belong to the present species.

HYPOTYPE. P.45664.

HORIZON AND LOCALITY. Hypotype from sample No. 21, Wadi El-Sharawna section.

Hedbergella petaloidea (Gandolfi)

1955 *Globotruncana* (*Rugoglobigerina*) *petaloidea petaloidea* Gandolfi : 52, pl. 3, figs. 13*a–c*.
1955 *Globotruncana* (*Rugoglobigerina*) *petaloidea subpetaloidea* Gandolfi : 52–53, pl. 3, figs. 12*a–c*.
1956 *Globigerina compressa* Plummer ; Hofker : 76, pl. 9, figs. 67*a–c*.
1960 *Rugoglobigerina jerseyensis* Olsson : 49, pl. 10, figs. 19–21.
1962 *Praeglobotruncana* (*Hedbergella*) *petaloidea* (Gandolfi) ; Berggren : 41–43, pl. 7, figs. 4*a–c*.

REMARKS. *Hedbergella petaloidea* ranges throughout the Maestrichtian part of the sections studied as a rare to common form. It is believed to have evolved into *Globotruncana havanensis* Voorwijk by the lateral compression of the chambers in the last whorl, by the development of a roughly concavo-convex test, by the confinement of the aperture to an interiomarginal-umbilical position, and by the development of the umbilical tegilla, the keel or keels and the imperforate peripheral band. This is suggested by the recorded tendency of *H. petaloidea* to shift the aperture to a somewhat umbilical position and to develop a pinched out pseudo-keel and slightly compressed chambers, and is substantiated by the several transitional stages which were described by Gandolfi as *G.* (*R.*) *petaloidea subpetaloidea*. However, both Gandolfi (1955) and Berggren (1962) considered *H. petaloidea* to have evolved from *G. havanensis*, despite the fact that the general tendency in the evolution of these forms is towards the development of carinate tests and more flattened chambers.

The species was originally described by Gandolfi (1955) from the Maestrichtian Colon shale of northeastern Colombia as *Globotruncana* (*Rugoglobigerina*) *petaloidea petaloidea*. However, its extraumbilical-umbilical aperture and weakly developed umbilical portici distinguish it from both *Globotruncana* and *Rugoglobigerina*, and justify its assignment to *Hedbergella*. Again, the form described by Gandolfi (1955) as *G.* (*R.*) *petaloidea subpetaloidea* differs from the present species in having only a weakly developed pseudocarina. However, as the tendency to have a pinched out periphery in the form of a pseudocarina was clearly observed in the central form, the latter subspecies falls well within its range of variation and is thus considered synonymous.

Olsson (1960) described as *R. jerseyensis* from the Maestrichtian Redbank formation of New Jersey, a form which is identical with the present species, while Hofker (1956*c*) confused it with *G. compressa* (Plummer) when he described the latter species from the Maestrichtian of northwestern Germany.

HYPOTYPE. P.45665.

HORIZON AND LOCALITY. Hypotype from sample No. 27, Wadi El-Sharawna section.

Family **GLOBIGERINIDAE** Carpenter, Parker & Jones 1862

Subfamily **GLOBIGERININAE** Carpenter, Parker & Jones 1862

Genus ***GLOBIGERINA*** d'Orbigny 1826

TYPE SPECIES. *Globigerina bulloides* d'Orbigny 1826.

1826 *Globigerina* d'Orbigny : 277 (Type species : *Globigerina bulloides* d'Orbigny 1826).
1956 *Globoconusa* Khalilov : 249 (Type species : *Globoconusa conusa* Khalilov, 1956).
1961 *Subbotina* Brotzen & Pozaryska : 160 (Type species : *Globigerina triloculinoides* Plummer 1926).

EMENDED DIAGNOSIS. Test free, trochospirally coiled, multiglobular ; dorsal side evolute, low trochospire or turreted ; ventral side umbilicate, strongly inflated ; equatorial periphery subcircular to ovoid, moderately to distinctly lobate ; axial periphery rounded ; chambers arranged in 2–4 whorls, dextrally or sinistrally coiled; all chambers seen on dorsal side, only those of last whorl seen on ventral side ; chambers generally spherical, ovate, slightly elongated radially or in direction of coiling, strongly inflated, but occasionally slightly compressed or gently appressed ; inter-cameral sutures on dorsal side curved or straight, depressed ; on ventral side generally radial and strongly depressed ; spiral suture curved, or rectispiral, depressed ; umbilicus very small or large, open ; aperture interiomarginal, umbilical, sometimes extending slightly towards the periphery, not as much as in *Globorotalia*, and sometimes provided with apertural lip ; previous apertures remain open into the umbilicus ; wall calcareous, perforate, radial in structure ; surface smooth, cancellated, pitted, reticulate, papillose, hispid or spinose.

DISCUSSION. d'Orbigny's original description of the genus *Globigerina* was so brief that several other genera, e.g. *Globorotalia*, *Hedbergella*, *Rugoglobigerina* and *Globotruncana*, were included in it, thus obscuring its stratigraphical range. However, *Globigerina* is distinguished by its globular, non-truncated chambers ; interiomarginal, umbilical apertures (which may in some cases extend slightly towards the periphery), its simple, open umbilicus and rounded axial periphery. Recent studies have defined the range of this genus as Danian–Recent, although it was previously extended to the Lower Cretaceous or even to the Upper Jurassic. However, the fact that no typical *Globigerina* has yet been recorded from the Upper Cretaceous makes the stratigraphical gap between the first appearance of *Globigerina* in the Lower Danian and the so-called *Globigerina* in the Upper Jurassic and the Lower Cretaceous too big, and casts doubt on the identification of the latter forms. Whether *Globigerina* is a polyphyletic genus which in the Upper Jurassic, branched off from a particular ancestor to die out in the Lower Cretaceous, and again from another ancestor in the basal Danian branched off to continue living up to now (as suggested by Bolli, Loeblich & Tappan 1957), or whether the Upper Jurassic–Lower Cretaceous forms are not true globigerinas are questions still unanswered, although the latter proposition seems most probable.

Khalilov (1956) described *Globoconusa* as a new genus, with *Globoconusa conusa* Khalilov as type species. It was distinguished by its high conical, turret-like test, although *Globoconusa quadripartitaformis* Khalilov 1956 was described as having a convex, rather than a turreted dorsal side. *Globoconusa conusa* Khalilov is a junior synonym of *Globigerina daubjergensis* Brönnimann 1953 a species which shows a marked variation in the height of its spire. Again, variation in the degree of elevation of the dorsal side is clearly observed within one and the same species, and between one species and another, and cannot be accepted as a generic character. Typical *globigerinas* with a highly raised dorsal side are known, and in the other closely related planktonic genera, forms with planoconvex, biconvex and spiroconvex test are included within the same genus and cannot be separated on the basis of the shape of the dorsal side.

Loeblich & Tappan (1964) emended the diagnosis of *Globoconusa* Khalilov adding, that the wall is characteristically spinose and that the aperture is a small, rounded umbilical opening, with one or more tiny, secondary sutural openings on the spiral side against the early whorl. However, they stated " Although *Globoconusa* was described as high-spired, the type species is quite variable as to height of spire." Again the holotype of *Globoconusa conusa* was described as having an umbilical aperture only, with no sutural apertures, as was its senior synonym *Globigerina daubjergensis* Brönnimann. Finally, if the surface spines are considered characteristic of the genus, it would not be possible to decide to which genus forms such as *Globigerina kozlowskii* Brotzen & Pozaryska (with a highly turreted spiral side and a delicately papillose surface) should be assigned.

Globoconusa Khalilov, as originally defined by its author, is a junior synonym of *Globigerina* d'Orbigny 1826. Forms with minute sutural apertures which were assigned to this genus by Loeblich & Tappan (1964) are not typical and should preferably be treated separately.

Morozova (1959) described *Globigerina* (*Eoglobigerina*) as a new subgenus, with *G.* (*E.*) *eobulloides* Morozova as type species. It was said to differ from *Globigerina* (*Globigerina*) d'Orbigny in its thin and smooth or microcellular test wall, and in the small size of its aperture. However, surface texture and size of aperture are characters of specific rather than subgeneric importance. Furthermore, since *Globigerina* (*Eoglobigerina*) *eobulloides* is a junior synonym of *Globorotalia pseudobulloides* (Plummer), *G.* (*Eoglobigerina*) is a junior synonym of *Globorotalia* Cushman. It should be noted that Morozova apparently included within *Globigerina* (*Eoglobigerina*) some Senonian species of *Hedbergella*, thus considering its range to be Senonian to Danian.

Brotzen & Pozaryska (1961) described *Subbotina* as a new genus, with *Globigerina triloculinoides* Plummer 1926 as the type species. *Subbotina* was said to differ from *Globigerina* d'Orbigny in having a reticulate surface with large pores which open on the surface in two funnel-shaped structures surrounded by a coronet or radiating pillars. These authors studied the wall structure of *Globigerina bulloides* d'Orbigny and concluded that it is completely different from the reticulate wall of *Globigerina triloculinoides*. As they found no transitional stages between these two types of wall texture, they separated the globigerinas with a reticulate surface as their new genus *Subbotina*, stating that " Le type réticulé . . . se trouve dans tout un group de prétendues *Globigerina*, mais étant donné que nous n'avons jamais trouvé trace de passage dans notre matériel ou dans le matériel publié, nous devons nous considérer comme obligés de séparer taxinomiquement ce groupe de *Globigerina* et de lui donner un nouveau nom de genre : *Subbotina* n.gen." However, both Hofker (1960*g*, *i*) and Berggren (1962) suggested the development of *Globigerina triloculinoides* Plummer, from *Globorotalia pseudobulloides* (Plummer), a species with a very finely pitted surface, which is believed to have evolved from forms with a smooth, finely perforate surface (see Berggren 1962 : 90). Again, *G. triloculinoides* Plummer is believed to have evolved into *G. inaequispira* Subbotina, a species with a less reticulate surface. Moreover, the surface texture in the various species of *Globigerina* varies from smooth, to hispid, papillose, nodose, spinose, pitted or reticulate. Variation in the surface texture from one species to another, and amongst members of the same species excludes the possibility that this feature alone can be used as a generic character. Thus the separation of globigerinas with a reticulate surface as a distinct genus cannot be accepted without a complete study of the various forms of surface texture and of their relationship to each other through the various evolutionary lineages in *Globigerina*. It is believed that different types of surface texture grade imperceptibly into one another. The suggested lineages in *Globigerina* (Text-fig. 13) show the gradual evolution of highly spinose, nodose forms from smooth-surfaced ones. Thus *Subbotina* Brotzen & Pozaryska 1961 is here considered a junior synonym of *Globigerina* d'Orbigny 1826.

Loeblich & Tappan (1964) emended the diagnosis of *Subbotina*, adding that the aperture is umbilical-extraumbilical, and stating that " The coarsely pitted surface is found in species with low and slightly extraumbilical aperture and distinctive lip, none of which is found in typical *Globigerina*." However, most *Globigerina* species show a slight tendency towards the extension of the aperture to a somewhat extra-umbilical position, but not as much as in true *Globorotalia*. Again, variation in the degree of elevation of the dorsal side, in the development of the apertural lip, and in surface texture are characters of specific, rather than generic importance. Moreover, *Subbotina* was described as having the same stratigraphical range as *Globigerina* d'Orbigny.

REMARKS. Eighteen species and subspecies of *Globigerina* are described in the present study, four species and one subspecies of which are new. These new forms are: *Globigerina alanwoodi* sp.nov., *G. arabica* sp.nov., *G. haynesi* sp.nov., *G. nodosa* sp.nov., and *G. triloculinoides parva* subsp.nov.

EVOLUTIONARY DEVELOPMENT OF *GLOBIGERINA*

The genus *Globigerina* was always thought to be the ancestral stock from which most globigerinids evolved, because its range was wrongly considered to be Upper Jurassic to Recent. However, as explained earlier, the Mesozoic records are probably incorrect. Moreover, the widespread faunal break between the Maestrichtian and the Danian makes it difficult to follow the early evolutionary development of the genus. Whether *Globigerina* has evolved from *Rugoglobigerina* by the loss of the tegilla and the meridional costellae, from *Hedbergella* by the confinement of the aperture to an interiomarginal, umbilical position and by the loss of the umbilical portici, or from the rounded *Globorotalia* by the confinement of the aperture to an interiomarginal, umbilical position, is still unknown. Nevertheless the recorded development of *Globigerina triloculinoides* Plummer from *Globorotalia pseudobulloides* (Plummer) (see Hofker 1960*g*, *i* ; Berggren 1962) may favour the last-mentioned proposition.

The present study of early representatives of the genus *Globigerina* throughout the Paleocene–Lower Eocene succession of the Esna–Idfu region has shown that the genus displays a marked tendency to increase its surface rugosity upwards in the section (see Text-fig. 13)

Globigerina alanwoodi sp. nov.

(Pl. 16, figs. 6*a*–*c*)

DIAGNOSIS. A *Globigerina* with large, robust, smooth-walled, multilocular test ; weakly raised dorsal side and strongly inflated ventral one ; numerous, inflated chambers which increase slowly in size ; wide umbilicus.

DESCRIPTION. Test large, robust, coiled in a low trochospire ; dorsal side almost flat, slightly inflated, with the early chambers very weakly raised over the circumambient last whorl ; ventral side strongly inflated and distinctly protruding ; equatorial periphery circular, slightly lobate ; axial periphery rounded ; chambers on the dorsal side 17, arranged in 3 dextrally coiled whorls ; the initial chambers are comparatively large, globular, slightly inflated and are followed by roughly ovoid, moderately inflated ones which are elongated in the direction of coiling and increase regularly in size ; the last whorl is composed of 7 large chambers which are crescentic in the early part, roughly quadrangular later, strongly elongated in the direction of coiling and increase slowly and regularly in size, except for the last chamber which is slightly smaller than the penultimate ; on the ventral side the chambers are 7, large, inflated and strongly protruding ; sutures on the dorsal side slightly curved, depressed ; on the ventral side they are straight, radial and strongly incised ; umbilicus wide, deep and open, aperture interiomarginal, umbilical ; wall calcareous, perforate ; surface smooth, except around the umbilicus where it becomes delicately papillose.

DIMENSIONS OF HOLOTYPE.

Maximum diameter = 0·47 mm.
Minimum diameter = 0·41 mm.
Thickness = 0·30 mm.

REMARKS. *Globigerina alanwoodi* sp. nov. is closely related to *G. mckannai* White from which it is distinguished by its perfectly smooth surface, and distinct stratigraphical range. It probably evolved into *G. mckannai* in Upper Paleocene time by the development of the granular spinose surface. On the other hand, it possibly evolved from the smooth surfaced, multilocular, *G. spiralis* Bolli, by flattening the dorsal side, increasing the size of test and the number of chambers in the last whorl and by developing a much wider umbilicus. The stratigraphical ranges of these forms agree with this proposition, although no direct evidence was recorded.

This species is named after Professor Alan Wood, of the Department of Geology, U.C.W., Aberystwyth

HOLOTYPE. P.45567.

PARATYPES. P.45568.

HORIZON AND LOCALITY. Holo- and paratypes, from sample No. 43, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globigerina alanwoodi* is restricted to the lower Upper Paleocene, ranging throughout the *G. pseudomenardii* Subzone as a rare to " flood " form in the sections studied.

Globigerina aquiensis Loeblich & Tappan

1957*a* *Globigerina aquiensis* Loeblich & Tappan : 180, pls. 51, figs. 4*a*–5*c* ; pl. 56, figs. 4*a*–6*c*.
? 1960*a* *Globigerina aquiensis* Loeblich & Tappan ; Berggren : 65–66, pl. 1, figs. 1*a*–2*c* ; pl. 7, figs. 1*a*–2*c*.

REMARKS. *Globigerina aquiensis* was first described by Loeblich & Tappan (1957*a*) from the Aquia formation of Maryland and Virginia and the Vincentown formation of New Jersey, which they considered to be of Upper Landenian (Sparnacian) age.

Berggren (1960*a*) described this species from the Lower Eocene of northwestern Germany, while Gartner & Hay (1962) recorded it from the type Ilerdian of Spain and the Ilerdian " marne blanche " of Mont Cayala, France. The latter authors included *G. kozlowskii* Brotzen & Pozaryska in the synonymy of this species, although the morphological characters and stratigraphical distribution of these two species strongly oppose this proposition.

Globigerina aquiensis is distinguished by its small, inflated, moderately to relatively high, trochospirally coiled test ; its chambers which increase moderately in size and which are elongated in the direction of coiling ; its small umbilicus ; and finely hispid surface. It is very closely related to *G. haynesi* sp. nov. (p. 165) from which it has probably evolved, and to *G. pseudocorpulenta* Khalilov which might possibly have evolved from it, although no direct evidence was recorded.

In the Esna–Idfu region, *G. aquiensis* is rare in the upper part of the *G. velascoensis* Zone, the *G. aequa*/*G. esnaensis* Subzone of Upper Paleocene age, and gradually fades out in the overlying Lower Eocene *G. wilcoxensis* Zone.

HYPOTYPE. P.45569.

HORIZON AND LOCALITY. Hypotype from sample No. 63, Gebel Owaina section.

Globigerina arabica sp. nov.
(Pl. 18, figs. 6*a*–*c*)

DIAGNOSIS. A *Globigerina* with large, moderately to highly spired, smooth-walled test ; radial, incised sutures on both sides ; chambers increasing slowly in size.

DESCRIPTION. Test large, globular, inflated and coiled in a high trochospire ; dorsal side convex, strongly inflated with the early chambers almost on the same level and distinctly raised above those of the last whorl ; ventral side moderately inflated ; equatorial periphery subcircular, distinctly lobate ; axial periphery rounded ; the 18 chambers on the dorsal side increase slowly in size and are arranged in 2½ dextrally coiled whorls ; the last whorl is composed of 6, large, subglobular chambers ; on the ventral side the chambers are 6, large, globular, strongly inflated and increase slowly in size except for the third which is much smaller than the others ; sutures on both sides almost straight, radial and strongly depressed ; umbilicus small, deep and open (although it is filled with calcite growth and foreign material in the figured specimen) ; aperture interiomarginal umbilical, an ovoid, large opening with thick calcite growth around it ; wall calcareous, perforate ; surface smooth.

DIMENSIONS OF HOLOTYPE.

Maximum diameter	=	0·46 mm.
Minimum diameter	=	0·39 mm.
Maximum thickness	=	0·29 mm. (across the middle part of test)

VARIATION. The main variation observed is in the degree of elevation of the dorsal side which can be either weakly raised or coiled in a very high trochospire ; coiling is random, with more tendency to dextral forms.

REMARKS. *Globigerina arabica* sp. nov. is distinguished from *G. spiralis* Bolli by its much larger size, less elevated initial spire and more globular, inflated chambers. In *G. spiralis* each whorl is higher than the following one and thus the dorsal side is more or less conical in shape, while in *G. arabica* the first two whorls are more or less in the same level but distinctly higher than the last.

The presence of the peculiar calcite growth in the umbilicus and around the aperture made it difficult to determine the taxonomic position of this species with certainty. It is, therefore, included in *Globigerina* for the time being on the basis of its other morphological features.

Globigerina arabica has probably evolved from *Globorotalia trinidadensis* Bolli by the elevation of the early whorls, the reduction of the rate of growth, and the confinement of the aperture to an interiomarginal, umbilical position. Forms of *G. trinidadensis* with slightly raised early chambers are believed to be transitional to the present species. *G. arabica* is also believed to have evolved into *G. spiralis* Bolli, as substantiated by the morphological characters and stratigraphical distribution of these two species.

HOLOTYPE. P.45570.

PARATYPES. P.45571.

HORIZON AND LOCALITY. Holo- and paratypes, from sample No. 30, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globigerina arabica* sp. nov. ranges throughout the Upper Danian part of the sections studied, (the Lower and Middle Danian being missing). It does not cross the Danian–Middle Paleocene boundary.

Globigerina bacuana Khalilov

1956 *Globigerina bacuana* Khalilov : 235, pl. 3, figs. 4*a–c*.

REMARKS. *Globigerina bacuana* Khalilov is one of three morphologically similar *Globigerina* species which are distinguished from each other by the surface texture. These three species are :

1. *Globigerina bacuana* Khalilov, 1956, with a densely pitted surface.
2. *Globigerina aquiensis* Loeblich & Tappan 1957*a*, with a finely hispid surface.
3. *Globigerina haynesi* sp. nov. with a delicately papillose surface.

Globigerina bacuana is distinguished by its large, robust test which is coiled in a low to moderately high trochospire ; its 4 large, subglobular, chambers in the last whorl which increase rapidly in size ; its almost straight, radial, depressed sutures ; narrow umbilicus ; and distinctly pitted surface. It is believed to have evolved from *G. haynesi* sp. nov. by the development of the pitted surface.

HYPOTYPE. P.45572.

HORIZON AND LOCALITY. Hypotype from sample No. 60, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globigerina bacuana* was first described by Khalilov (1956) from the Upper Paleocene and the Lower Eocene of Azerbaidzhan and Turkman, U.S.S.R.

In the Esna–Idfu region *G. bacuana* occurs as a rare form in the upper part of the *G. velascoensis* Zone, the *G. aequa*/*G. esnaensis* Subzone of upper Upper Paleocene age.

Globigerina belli White

1928*a* *Globigerina belli* White ; 192, pl. 27, figs. 11*a–c*.

REMARKS. Although White's original figures are not clear and his description is incomplete, the present form most probably belongs to this species.

Globigerina belli White is distinguished by its large, globular, trochospirally coiled test ; raised dorsal side and inflated ventral one ; numerous, large roughly globular chambers which increase moderately in size on the dorsal side (except for the last, which is generally smaller than the penultimate and strongly elongated and curved over the ventral side thus covering most of the umbilicus) ; chambers on the ventral side inflated, globular, slowly increasing in size ; last chamber peculiar in shape ; straight, incised sutures on both sides ; narrow umbilicus ; and sugary-textured surface.

G. belli is probably the ancestral stock from which most of the multilocular, highly-spired Paleocene *Globigerina* species have evolved. It has possibly evolved directly into *G. spiralis* Bolli, or indirectly via *G. arabica* sp. nov., although no direct evidence was recorded.

HYPOTYPE. P.45573.

HORIZON AND LOCALITY. Hypotype from sample No. 7, Gebel El-Kilabiya section.

Stratigraphical range. *Globigerina belli* was described by White (1928) as " being of rare occurrence in the uppermost Mendez, becoming common in the very base of the Velasco, and rapidly diminishing, till disappearing a short distance above the base ". Apparently, White confused the present species with morphologically similar *Rugoglobigerina* species from the Upper Maestrichtian, and thus extended its range to the uppermost Mendez. However, in the Esna–Idfu region *G. belli* occurs as a rare form in the Danian *G. compressa/G. daubjergensis* Zone and in the basal part of the overlying *G. angulata* Zone of Middle Paleocene age.

Globigerina chascanona Loeblich & Tappan

(Pl. 16, figs. 4*a–c*)

1957*a* *Globigerina chascanona* Loeblich & Tappan : 180–181, pls. 49, figs. 4*a*–5*c* ; pl. 61, figs. 8*a–c*.

1960*a* *Globigerina chascanona* Loeblich & Tappan ; Berggren : 66–67, pl. 1, figs. 3*a–c* ; pl. 7, figs. 3*a*–4*c*.

Description. Test medium-sized, coiled in a moderately high trochospire, inflated ; dorsal side slightly raised, with the early whorls moderately elevated above the level of the final whorl ; ventral side quadriglobular, strongly inflated ; equatorial periphery subquadrate to roughly ovoid, lobate ; axial periphery rounded ; chambers on the dorsal side about 12 in number, increasing moderately in size and arranged in 2½ sinistrally coiled whorls ; the initial chambers are small, inflated, globigerine, almost masked by the surface rugosity and are followed by large, roughly ovoid chambers ; the last whorl is composed of 4½, large, slightly ovoid to roughly quadrate chambers ; on the ventral side the chambers are 4½, large, globular, strongly inflated, overlapping and pushed forward towards the much-narrowed umbilicus ; sutures on the dorsal side short, very slightly curved to almost straight, depressed ; on the ventral side they are slightly curved, almost radial and strongly depressed ; umbilicus very narrow, shallow and open, with the last chamber strongly pushed over it ; aperture interiomarginal, umbilical ; surface distinctly nodose, with the nodes tapering out especially along the periphery and on the ventral side in the form of thick stout, spine-like projections, giving the surface a very prominently spinose appearance.

Dimensions of described specimen.

Maximum diameter	=	0·38 mm.
Minimum diameter	=	0·32 mm.
Thickness	=	0·28 mm.

Remarks. This species is distinguished by its small to medium-sized, tightly coiled, medium to relatively highly spired, prominently spinose test ; its narrow umbilicus ; overlapping chambers on the ventral side, and slightly curved depressed sutures.

Loeblich & Tappan (1957*a*) showed a wide range of variation in the degree of elevation of the dorsal side of *G. chascanona*, from a very highly trochospirally coiled test and a high, conical dorsal side in their holotype (pl. 49, figs. 5*a–c*), to forms with a moderately convex dorsal side (e.g. pl. 49, figs. 4*a–c*) or even a flat dorsal side (e.g. pl. 61, figs. 8*a–c*).

Globigerina chascanona has probably evolved from *G. aquiensis* Loeblich & Tappan, by the development of the prominently spinose surface. The morphological characters and stratigraphical ranges of the two species support this proposition. Specimens of *G. chascanona* from the Esna–Idfu region conform well with Loeblich & Tappan's original description and figures although they are slightly larger.

HYPOTYPE. P.45574.

HORIZON AND LOCALITY. Figured specimen from sample No. 64, Gebel Owaina section.

STRATIGRAPHICAL RANGE. Loeblich & Tappan (1957*a*) described *G. chascanona* from the Hornerstown formation of New Jersey and the Aquia formation of Virginia, as well as from the Nanafalia formation of Alabama which they considered as Upper Landenian (Sparnacian) and Lower Eocene respectively. But, as previously mentioned, both Bramlette & Sullivan (1961) and Gartner & Hay (1962) considered the Nanafalia formation to be of Paleocene rather than of Lower Eocene age.

G. chascanona was also recorded from the Lower Eocene of northwestern Germany (Berggren 1960*a*), and from the type Ilerdian of Spain (Gartner & Hay 1962), although Berggren's forms appear to be somewhat different from the type specimens of *G. chascanona*.

In the Esna–Idfu region, *G. chascanona* is rare in the upper part of the Upper Paleocene *G. velascoensis* Zone and dies out completely below the overlying Lower Eocene *G. wilcoxensis* Zone.

Globigerina daubjergensis **Brönnimann**

(Pl. 15, figs. 3*a–c*)

1953 *Globigerina daubjergensis* Brönnimann : 340–341, text-fig. 1.

1956 *Globoconusa conusa* Khalilov : 249, pl. 5, figs. 2*a–c*.

1957*b* *Globigerina daubjergensis* Brönnimann ; Bolli : 70, pl. 16, figs. 13–15.

1957 *Globigerina daubjergensis* Brönnimann ; Troelsen : 128, pl. 30, figs. 1*a*–2*c*.

1957*a* *Globigerinoides daubjergensis* (Brönnimann) Loeblich & Tappan (pars) : 184–185, pl. 40, ? figs. 1*a–c*, 8*a–c* ; pl. 41, figs. 9*a–c* ; pl. 42, ? figs. 6*a*–7*c* ; pl. 43, figs. 1*a–c* ; pl. 44, ? figs. 7–8*c*.

1959*a* *Globigerina daubjergensis* Brönnimann ; Hofker : 22, text-fig. 5.

1960 *Globigerinoides daubjergensis* (Brönnimann) : Olsson : 43, pl. 8, figs. 4–6.

1960*a* *Globigerina daubjergensis* Brönnimann *primitiva* Hokfer (pars) : 226, ? text-fig. 25 ; 228, text-fig. 34.

1960*a* *Globigerina* cf. *daubjergensis* Brönnimann ; Hofker : 228, text-fig. 36.

1960*d* *Globigerina daubjergensis* Brönnimann ; Hofker (pars) : 34–41, pl. 3, (? Danian II, Danian III, Danian IV, non Danian V, non white chalk of Denmark ; non Cr 4, non Mc, ? holes in hard ground, non Lower Paleocene of Holland) ; non pl. 1, figs. B, E ; non pl. 2, fig. B.

1960*g* *Globigerina daubjergensis* Brönnimann ; Hofker : 74–76, text-figs. 29*a*–34*b*, table 4.

1960*i* *Globigerina daubjergensis* Brönnimann ; Hofker : 119–120, pl. 1, figs. 1–8.

DESCRIPTION. Test very small, coiled in a high trochospire ; dorsal side broadly conical with a sharply pointed initial part and inflated later part ; ventral side quadriglobular, inflated ; equatorial periphery quadrate, distinctly lobate ; axial periphery rounded ; chambers on the dorsal side appear to be 16–19 in number, arranged in 4 dextrally coiled whorls ; the initial chambers are extremely small, indistinct, slightly inflated, globigerine and increase slowly and regularly in size to the beginning of the last whorl, where the chambers increase rapidly in size ; the last whorl thus constitutes most of the test, while the early chambers constitute a minute, high, trochoid spire ; the last whorl is composed of 4, relatively large, almost globular chambers ; on the ventral side the chambers are 4, relatively large, globular and inflated ; sutures on the dorsal side curved, depressed in the early part, straight and strongly incised later ; on the ventral side the sutures are straight, radial, strongly incised, set almost at right angles to each other in a cruciform pattern which emphasizes the quadrate shape of the test ; umbilicus exceedingly small, almost closed and indistinct ; aperture interiomarginal, umbilical ; wall calcareous, finely perforate ; surface rough, hispid, covered by minute, delicate spines, and very small scattered papillae.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·175 mm.
Minimum diameter = 0·130 mm.
Thickness = 0·160 mm.

MAIN VARIATION.

1. The test is minute to small (maximum diameter ranges from 0·12 to 0·28 mm.)
2. The dorsal spire may be moderately raised to high.
3. The number of chambers in the last whorl is 3–4, 3½ is most common.
4. Coiling is fairly random but tends to be dextral ; (of 175 specimens studied, 98 coiled dextrally).
5. The small, shallow, open umbilicus may be partially closed by the slightly overlapping last chamber.
6. The fine surface spines are always present and may be prominent and numerous or very faint and scattered.

REMARKS. *Globigerina daubjergensis* Brönnimann is distinguished by its extremely small, trochospirally coiled test, its minute, pointed spire on the dorsal side, its rough, finely spinose wall surface, its small shallow umbilicus and small umbilical aperture, its strongly depressed sutures on both sides, and distinctly lobate periphery.

Because of its extremely small size, this excellent Danian guide fossil was probably overlooked in the past or lumped together with superficially similar *Globigerina* species. Troelsen (1957) recorded this species from the type Danian and from various Danian outcrops in Scandinavia, where he noticed, for the first time, the occurrence of small, accessory, sutural apertures on the dorsal side of some of the specimens. These accessory apertures caused disagreement whether the species should be referred to *Globigerina* or to *Globigerinoides*, and the problem was further complicated by the fact that specimens with and specimens without accessory apertures were found together. Troelson added " Small accessory apertures commonly occur along the sutures of the final chamber, but the writer has, nevertheless, refrained from referring the species to the (probably polyphyletic) genus *Globigerinoides*."

Bolli (1957*b*), Hofker (1959*a*, 1960*a*, *d*, *g*, *i*, 1961*d*, 1962*a*), Bolli & Cita (1960*a*, *b*), and Berggren (1962) considered the species to belong to the genus *Globigerina* although both Hofker and Berggren clearly described and figured these dorsal openings.

Loeblich & Tappan (1957*a*, *b*) followed by Olsson (1960) and Hillebrandt (1962), removed this species to the genus *Globigerinoides*, while Reichel (1953) and Bermudez (1961) considered it to be a ? *Globigerina*.

Loeblich & Tappan figured the dorsal views of 7 specimens, only four of which were shown to have supplementary apertures ; they said nothing about the forms without supplementary apertures, nor did they say to which genus these forms should be referred if the species is removed to the genus *Globigerinoides*. Hofker (1959*a*, 1960*a*, *d*, *g*, *i*, 1961*d*, 1962*a*) and Berggren (1962) tried to explain that these dorsal openings are slight morphological variations in the evolutionary development of the species, and do not warrant its removal to the genus *Globigerinoides*.

These so-called supplementary apertures were not observed in specimens of *G. daubjergensis* from the Esna–Idfu region. Brönnimann (personal communication, April 2, 1963) stated that : " The type of *Globigerina daubjergensis* Brönnimann does not have any additional apertures, and the removal to the genus *Globigerinoides* does not seem to be justified." Thus, it is here suggested that the typical *G. daubjergensis* does not have supplementary apertures, that forms with supplementary apertures should be considered separately, and that the removal of the species to the genus *Globigerinoides* is not warranted. However, in the very closely related *Globigerina kozlowskii* Brotzen & Pozaryska which is associated with *G. daubjergensis* in the Upper Danian, and is believed to have evolved from it, occasional, minute, sutural openings were observed, but seem to be different from the typical *Globigerinoides* sutural apertures. A detailed study of a whole population of each of these two species at their type localities is essential to establish their relationship and explain the true nature of these supplementary apertures. It is not excluded, that forms described as *G. daubjergensis* with sutural apertures are actually *G. kozlowskii* and that the latter represents the ancestral stock from which the genus *Globigerinoides* has evolved.

Khalilov (1956) described *Globoconusa* as a new genus with *Globoconusa conusa* Khalilov as type species. Examination of the description and figures of the latter species showed clearly that it is a junior synonym of *Globigerina daubjergensis* Brönnimann 1953, and that *Globoconusa* is a junior synonym of *Globigerina* d'Orbigny 1826, as mentioned above.

Hofker (1959*a*, 1960*a*, *d*, *g*, *i*, 1962*a*) studied the orthogenetic changes in the development of *G. daubjergensis* in the Danian rocks of Denmark, Holland and Belgium. Apparently he had confused *G. daubjergensis* with small forms of Maestrichtian *Rugoglobigerina* and *Hedbergella* species and also with younger *Globigerina* species in the overlying Middle Paleocene greensands such as *Globigerina kozlowskii*, thus obscuring the stratigraphical range and morphological characteristics of the species. This may be mainly due to the occurrence of mixed Maestrichtian–

Paleocene fauna in holes in the hard ground on top of the Md of Holland and Denmark, and to repeated attempts by Hofker to equate the type Maestrichtian with the type Danian, and to build bioseries representing continuous evolution from the Upper Cretaceous to the basal Tertiary.

The evolutionary trends suggested by Hofker (1960*g*, *i*) for *G. daubjergensis* can be summarized as follows :

1. A gradual increase in the size of test and a decrease in the density of spines on the walls of the last-formed chambers upwards in the section.
2. The development of small openings on the dorsal side from the Middle Danian onwards ; these become more frequent higher in the section.
3. The increase in the size of the last-formed chambers, which may, in the highest levels of the Danian and in the overlying greensands, cover the whole umbilical region and the visible aperture (*Catapsydrax* character).

This clearly shows that Hofker confused *G. daubjergensis* with forms such as *G. kozlowskii* ; the former was not reported to cross the Danian–Middle Paleocene boundary, while the latter was reported from the middle and Upper Paleocene where it was said to display both the *Globigerinoides* and *Catapsydrax* characters assigned by Hofker to *G. daubjergensis* in its later stages of development. However, this evolutionary series was partially substantiated by Berggren (1962) in his study of specimens from southern Scandinavia, but it is probable that he had also confused *G. daujergensis* with the early stages of *G. kozlowskii.*

In the Esna–Idfu region, it was not possible to follow the evolutionary development of the species as suggested by Hofker, because the Lower and Middle Danian are missing. However, the specimens studied show a general tendency to increase the size of test and to reduce the surface rugosity on the chambers of the last whorl. Hofker (1960 *g*, *i*) greatly overemphasized the value of these continuous morphological changes in *G. daubjergensis* as tools in working out the detailed stratigraphy of the Danian stage. Without belittling these observations, it has to be stated that the distinct stages, mentioned by Hofker, are most probably distinct species, and that in a single species population, a wide range of variation was observed.

The physical and biological break at the base of the Danian made it difficult to trace the ancestral stock from which *G. daubjergensis* had evolved. This might have been any of the apparently similar *Rugoglobigerina* or *Hedbergella* forms which flood the Maestrichtian rocks below. Again, it is believed that *G. daubjergensis* evolved into *G. kozlowskii* since all transitional stages between them have been recorded. On the other hand, *G. daubjergensis* is believed to be related to the similarly trochospirally coiled forms, *G. chascanona* Loeblich & Tappan and *G. spiralis* Bolli, although no direct evidence was recorded.

HYPOTYPE. P.45575.

HORIZON AND LOCALITY. Figured specimen, from sample No. 7, Gebel El-Kilabiya section.

STRATIGRAPHICAL RANGE. The species was first described from the uppermost Danian (Zone D) of a quarry southwest of Stavnsbjerg farm, Daubjerg (Davbjerg), Jutland, Denmark, considered by Berggren (1962) as Middle Danian.

Troelsen (1957 : 127, text-fig. 4) and Berggren (1962 : 18, 84, test-fig. 2) showed that *G. daubjergensis* appears for the first time at the base of the Danian in its type area, and ranges throughout the whole Danian stage of Scandinavia, becoming particularly abundant in the upper part where it commonly dominates the planktonic fauna. It was also recorded from the Danian rocks of Denmark, Holland and Belgium (Hofker 1956*a*, 1959*a*, 1960*a*, *d*, *g*, *i*, 1961*d*, 1962*a*) ; from the basal Paleocene *Globorotalia trinidadensis* Zone of the lower Lizard Springs formation of Trinidad (Bolli 1957*b*) ; from the Danian of Sweden and of the Gulf and Atlantic Coastal plains (Loeblich & Tappan 1957*a*, *b*) ; from the basal part of the Hornerstown formation of New Jersey, which is considered of Danian age (Olsson 1960) ; from the *Globorotalia trinidadensis* Zone of the Paderno d'Adda section of northern Italy, which is regarded to be of Lower Danian age (Bolli & Cita 1960*a*, *b*) ; from the basal part of the Velasco formation of Mexico (Lower Danian) (Hay 1960) ; from the Paleocene of Cuba, Mexico and Venezuela (Bermudez 1961) ; from the Lower Paleocene of the Gubbio section, Italy (Luterbacher & Premoli Silva 1962) and from the basal Paleocene of Austria (Hillebrandt 1962).

All reliable references show clearly that *G. daubjergensis* is an excellent index fossil for the Danian; that it ranges throughout the whole stage, being most abundant at its top, and that it does not cross the Danian–Middle Paleocene boundary. All records of *G. daubjergensis* from rocks younger than the uppermost Danian are either erroneous, or of reworked specimens, while all records from rocks older than the basal Danian are actually *Rugoglobigerina* or *Hedbergella* species.

The assignment of the species to the Lower Danian only, as mentioned by Bolli & Cita (1960*a*, *b*) and Hay (1960), is apparently due to the fact that the first-mentioned authors had included the lower part of the Middle Paleocene, distinguished by the abundance of *G. angulata* (White), in their Upper Danian. Hay (1960) recorded *G. compressa* (Plummer) as ranging throughout the whole Danian, and *G. daubjergensis* as ranging through the lower part only, while all reliable references show that *G. daubjergensis* ranges throughout the whole Danian, while *G. compressa* is restricted to the Upper Danian.

In the Esna–Idfu region, *Globigerina daubjergensis* floods the Upper Danian part of the sections studied, (the Lower and Middle Danian being missing) and disappears completely before the first appearance of *G. angulata angulata* (White) of Middle Paleocene age. The apparently similar forms in the Middle Paleocene are actually *G. kozlowskii* Brotzen & Pozaryska.

Globigerina haynesi sp. nov.

(Pl. 15, figs. 5*a*–*c*)

Diagnosis. A *Globigerina* with relatively raised dorsal side and moderately inflated ventral one ; quadrate, lobate equatorial periphery ; depressed sutures ; very narrow umbilicus and delicately papillose surface.

Description. Test medium-sized, coiled in a relatively high trochospire ; dorsal side subconical, inflated ; ventral side quadriglobular, moderately inflated; equatorial periphery quadrate, distinctly lobate, axial periphery rounded ; chambers on dorsal side 15, arranged in 2½ dextrally coiled whorls and increasing moderately in size ; the initial chambers are small, globular, inflated and are followed by subglobular or rather ovoid, large ones ; the last whorl is composed of 4, subglobular and strongly inflated chambers ; on the ventral side the chambers are 4, large, globular, strongly overlapping and moderately inflated ; sutures on the dorsal side slightly curved, strongly depressed ; on the ventral side they are almost straight, radial and strongly incised ; umbilicus extremely small, almost indistinct, slit-like, shallow and open ; aperture interiomarginal, umbilical, in the form of a long narrow arch with a delicate, small lip ; wall calcareous, perforate ; surface finely papillose.

DIMENSIONS OF HOLOTYPE.

Maximum diameter = 0·37 mm.
Minimum diameter = 0·34 mm.
Thickness = 0·26 mm.

MAIN VARIATION.

1. Chambers 12–16, arranged in 2½–3 tightly coiled whorls, and increasing moderately in size.
2. The last whorl is composed of 3½–4 chambers, 4 being most common ; the last chamber is usually slightly smaller than the penultimate.
3. Coiling is random with a tendency to dextral coiling ; (of 77 specimens studied, 49 coiled dextrally).

REMARKS. *Globigerina haynesi* sp. nov. was probably confused with one or more of the following distinct, but morphologically similar species :

Globigerina bacuana Khalilov
Globigerina spiralis Bolli
Globigerina aquiensis Loeblich & Tappan
Globigerina chascanona Loeblich & Tappan

It is distinguished from *G. bacuana* by its delicately papillose surface, high dorsal side, and raised initial whorls. *Globigerina spiralis* is distinguished by its smooth surface, greater number of chambers and of whorls, and more tightly coiled test. *Globigerina aquiensis* which is morphologically very similar to the present species, has a finely hispid surface instead of a delicately papillose one ; *G. chascanona* is distinguished by its prominently spinose surface.

Globigerina hayensi is believed to have evolved from *G. spiralis* Bolli ; specimens of *G. spiralis* with a faintly papillose surface are believed to be transitional to *G. haynesi*, and the stratigraphical ranges of the two species favour this hypothesis. On the other hand, *G. haynesi* probably evolved into *G. velascoensis* Cushman by developing a more tightly coiled test, with an angular, depressed spiral suture and a strongly appressed last chamber.

This species is named after Dr. J. R. Haynes of the Department of Geology, U.C.W., Aberystwyth.

HOLOTYPE. P.45576.

PARATYPES. P.45577.

HORIZON AND LOCALITY. Holo- and paratypes from sample No. 64, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species is common to abundant throughout the Middle and Upper Paleocene of the sections studied, and is rare in the uppermost part of the Danian.

Globigerina inaequispira Subbotina

(Pl. 15, figs. 8*a–c*)

1953 *Globigerina inaequispira* Subbotina : 69, pl. 6, figs. 1*a*–4*c*.

DESCRIPTION. Test large, almost triglobular, coiled in a low trochospire, and strongly inflated especially on the ventral side ; equatorial periphery almost trilobate, radially elongate, with each lobe perfectly rounded at the end and distinctly separated from the others ; axial periphery rounded ; chambers on the dorsal side 15, arranged in 3 dextrally coiled whorls ; the initial chambers are extremely small, globular, inflated, very tightly coiled ; they increase slowly in size, and are followed by relatively much bigger, globular and strongly inflated chambers which increase gradually in size towards the beginning of the last whorl ; the chambers increase slowly to moderately in size within the same whorl, but very rapidly from one whorl to another ; the last whorl, which constitutes most of the test, is composed of 4 very large, roughly globular, inflated chambers, which increase rapidly in size ; the last chamber is strongly elongated radially and constitutes more than one-third of the test ; on the ventral side the chambers are 4, globular, strongly inflated and increase rapidly in size ; intercameral sutures on both sides straight, radial and strongly incised ; spiral suture roughly angular, almost rectispiral and strongly depressed ; umbilicus roughly quadrate, wide, deep and open ; aperture interiomarginal, umbilical, with a thin lip of which remnants are still preserved ; wall calcareous, perforate ; surface delicately pitted, with the raised parts between the minute pits giving the surface a fine sugary texture.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·50 mm.
Minimum diameter = 0·36 mm.
Thickness = 0·27 mm.

REMARKS. *Globigerina inaequispira* is distinguished from other species by the great difference in size between the successive whorls ; its large, triglobular, radially elongate test ; its small, closely coiled early chambers, and large, loosely coiled, rapidly increasing later ones ; its large, ovoid, radially elongate last chamber ; its roughly angular, depressed spiral suture, and straight, radial, depressed intercameral ones ; its distinctly lobate periphery, and finely pitted surface.

The forms described as *G. inaequispira* by both Loeblich & Tappan (1957*a*) and Olsson (1960) are completely different from Subbotina's original description and figures, while that described by Hillebrandt (1962) lacks the radially elongate terminal chamber characteristic of the species. The form described by Gartner & Hay (1962) as *G. inaequispira*, may be *G. stonei* Weiss.

G. inaequispira is believed to have evolved from *G. triloculinoides* Plummer.

HYPOTYPE. P.45578.

HORIZON AND LOCALITY. Figured specimen, from sample No. 49, Gebel Owaina section.

STRATIGRAPHICAL RANGE. Subbotina (1953) described *G. inaequispira* from the " zone of conical *Globorotalias* " of the northern Caucasus which she considered as Lower to Middle Eocene. However, Berggren (1960*d*) considered this zone, on the basis of its pelagic foraminiferal content, to indicate an Upper Paleocene–Lower Eocene age.

In the Esna–Idfu region, *G. inaequispira* appears in the lower part of the Middle Paleocene *G. angulata* Zone. It continues as a rare to common form up to the Upper Paleocene *G. velascoensis* Zone, fades out gradually in the top part of this zone, dying out completely below the overlying *G. wilcoxensis* Zone.

Globigerina kozlowskii Brotzen & Pozaryska

(Pl. 15, figs. 1*a–c*, 2)

1961 *Globigerina kozlowskii* Brotzen & Pozaryska : 162–164, pls. 1–3.

DESCRIPTION. Test small, coiled in a high trochospire, inflated ; dorsal side broadly conical with a sharply pointed initial part, and strongly inflated later part ; ventral side strongly inflated ; equatorial periphery broadly ovoid and distinctly lobate, axial periphery rounded ; chambers on the dorsal side about 13 in number, arranged in 3 sinistrally coiled whorls ; initial chambers extremely small, indistinct, inflated, globigerine, increasing slowly in size up to the beginning of the last whorl, where they start to enlarge so rapidly that the final whorl constitutes most of the test; the last whorl is composed of $3\frac{1}{2}$, relatively large, roughly globular and strongly inflated chambers ; on the ventral side the chambers are $3\frac{1}{2}$, relatively large, globular and inflated ; sutures on the dorsal side curved, depressed in the early part, straight and strongly incised between the later chambers ; on the ventral side they are nearly straight, radial and strongly depressed; umbilicus very small, shallow and nearly closed ; aperture interiomarginal umbilical ; wall calcareous, finely perforate; surface finely papillose.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter	=	0·24 mm.
Minimum diameter	=	0·20 mm.
Thickness	=	0·19 mm.

VARIATION. The main variation observed in the rare specimens of *G. kozlowskii* studied is in the occasional presence of minute, sutural openings and/or small, senile chambers in some specimens, and in the size of the umbilicus which may sometimes be closed.

REMARKS. *G. kozlowskii* is believed to have evolved from *G. daubjergensis* Brönnimann in the uppermost Danian by the increase in the size of test, and the development of a finely papillose surface instead of the finely spinose one characteristic of *G. daubjergensis*. Transitional stages between these species are recorded in the present study, and both their morphological features and stratigraphical ranges strongly support this hypothesis.

Brotzen & Pozaryska, in their original description of the species, recorded a wide range of variation, which included specimens with typical *Globigerina* characteristics, and others with small, accessory, sutural apertures and/or an additional chamber covering the umbilicus. These forms conform well with the three stages suggested by Hofker (1960*g*, *i*) in the development of *G. daubjergensis* Brönnimann which he had described as the *Globigerina*, the *Globigerinoides*, and the *Catapsydrax* stages respectively. However, as none of these stages was recorded by Brönnimann in his original description, it is possible that Hofkers " *Globigerinoides* and *Catapsydrax* stages " are actually the early representatives of *G. kozlowskii*.

These various, distinct stages in the same species population, recorded by Brotzen & Pozaryska, made it difficult to decide with certainty the taxonomic position of the species. However, these authors considered the wall structure of the test to be the main criterion for classification, and as *G. kozlowskii* was said to have the same wall structure as typical *Globigerina*, it was considered to belong to *Globigerina s.l.*, in spite of the accessory sutural apertures and the umbilical bulla.

The form here described as *G. kozloskii* is a typical *Globigerina* as it has neither the accessory sutural apertures, nor the umbilical bulla. However, these minute sutural apertures were observed in a few specimens in the same population. Until further study of populations of both *G. kozlowskii* and *G. daubjergensis* in their type areas explains why these species apparently show the characters of more than one genus, the present species is considered to belong to the genus *Globigerina*. It should be noted that the holotype of *G. kozlowskii* was clearly shown to have accessory sutural apertures. Retention of the species in *Globigerina* is further justified by the fact that these accessory apertures appear to be different from those of typical *Globigerinoides* species, and are only very feebly represented in the specimens from the Esna–Idfu region and in topotype material kindly sent to the author by Dr. K. Pozaryska. Forms with an additional chamber covering the umbilicus (umbilical bulla) were not encountered in the samples studied, and were only recorded as rare in the type area.

G. kozlowskii is possibly related to the similar, highly trochospirally coiled, Paleocene forms such as *G. chascanona* Loeblich & Tappan, *G. aquiensis* Loeblich & Tappan, and *G. spiralis* Bolli.

Gartner & Hay (1962) considered *G. kozlowskii* to be a junior synonym of *G. aquiensis* Loeblich & Tappan, although the latter is clearly distinguished by its roughly quadrangular chambers which increase slowly in size and are slightly elongated in the direction of coiling, and by its wider umbilicus and spinose surface.

HYPOTYPE. P.45579.

HORIZON AND LOCALITY. Figured specimen, from sample No. 7 Gebel El-Kilabiya section.

STRATIGRAPHICAL RANGE. The species was first described from the Paleocene of the " Pamietowo " well of northern Poland. Brotzen & Pozaryska (1961 : 156) recorded the Maestrichtian in this well as unconformably overlain by a very thin Danian section (1 metre thick) which is conformably overlain successively by the Paleocene and the Lower Eocene. Their Paleocene was divided into three successive zones, lower, middle and upper. Apparently they considered the Danian separately from the Paleocene, but described strata with a typical Upper Danian fauna as lower Paleocene. This is proved by the occurrence of *G. compressa* (Plummer), a typical Upper Danian index fossil, in what they described as Lower Paleocene (above the Danian), and by the first appearance of *G. angulata* (White), a typical Danian–Middle Paleocene boundary marker, in their so-called Middle Paleocene. Again they described *G. acuta* Toulmin, an Upper Paleocene guide fossil, from their Lower Eocene. According to the distribution of pelagic species in their section, both their Danian and Lower Paleocene actually represent the Upper Danian, their middle and upper Paleocene are in fact Middle Paleocene, and their Eocene is the Upper Paleocene.

Brotzen & Pozaryska (1961) recorded this species as ranging from the uppermost part of the Danian through the Middle Paleocene (as interpreted here) being most typically developed in the latter. The species was stated to be rare higher in the section where it shows all the peculiar variations, while below the uppermost Danian the specimens were merely considered as variations of *G. daubjergensis*.

In the Esna–Idfu region *G. kozlowskii* appears in the uppermost Danian with forms transitional to *G. daubjergensis* Brönnimann ; it crosses the Danian–Middle Paleocene boundary and occurs as a rare form in the lower part of the *G. angulata* Zone.

Globigerina mckannai White

(Pl. 16, figs. 5*a*–*c*)

1928*a* *Globigerina mckannai* White : 194, pl. 27, figs. 16*a*–*c*.
1947 *Globorotalia pentacamerata* Subbotina : 128, pl. 7, figs. 12–17, pl. 9, figs. 24–26.
1950 *Globigerina cretacea* var. *esnehensis* Nakkady : 689, pl. 90, figs. 14–16.
1952*b* *Globigerina gravelli* Brönnimann : 12–13, pl. 1, figs. 16–18.
1953 *Acarinina pentacamerata* (Subbotina) Subbotina : 233, pl. 23, figs. 8*a*–*c* ; pl. 24, figs. 1*a*–9*c*.
? 1955 *Globorotalia pentacamerata* Subbotina; Maslakova : 84, pl. 14, figs. 7–9.
? 1956 *Globigerina dubia* Egger var. *lakiensis* Haque : 174–175, pl. 4, figs. 2*a*–*c*.
? 1956 *Globorotalia pentacamerata* Subbotina ; Sjutskaja : 103–104, pl. 4, figs. 6*a*–*c*.
1957*b* *Globigerina gravelli* Brönnimann ; Bolli : 72, pl. 16, figs. 1–3.
?1957*b* *Globorotalia mckannai* (White) Bolli : 79, pl. 19, figs. 16–18.
1957*a* *Globigerina mckannai* White ; Loeblich & Tappan (pars) : 181–182, pl. 53, figs. 1*a*–2*c* ; pl. 57, figs. 8*a*–*c* ; ? pl. 47, figs. 7*a*–*c* ; ? pl. 62, figs. 5*a*–7*c*.
? 1957*a* *Globotalia strabocella* Loeblich & Tappan : 195, pl. 61, figs. 6*a*–*c*.
1958*b* *Globigerina gravelli* Brönnimann ; Hornibrook : 665, pl 2, figs. 21, 25.
1960 *Globorotalia strabocella* Loeblich & Tappan ; Olsson : 48–49, pl. 10, figs. 10–12.
1960 *Globorotalia mckannai* (White) ; Bolli & Cita : 23–24, pl. 31, figs. 6*a*–*c*.
1960*a* *Globigerina mckannai* White ; Berggren (pars) : 68–71, pl. 9, figs. 3*a*–4*c* only ; non pl. 1, figs. 4*a*–*c* ; pl. 9, figs. 2*a*–*c* ; pl. 10, figs. 1*a*–*c*, text-fig. 7.
1960 *Globorotalia pentacamerata* Subbotina ; Said : 283, pl. 1, figs. 4*a*–*c*.
1961 *Globorotalia pentacamerata* Subbotina ; Said & Kerdany : 329, pl. 1, figs. 15*a*–*c*.

1962 *Globorotalia* (*Acarinina*) *mckannai* (White) ; Hillebrandt : 140–141, pl. 14, figs. 8*a*–10*c*.

1962 *Globorotalia* (*Acarinina*) *pentacamerata* Subbotina ; Hillebrandt : 142, pl. 14, figs. 7*a*–*c*.

DESCRIPTION. Test large, coiled in a low trochospire ; dorsal side very slightly raised, moderately inflated, ventral side highly raised and strongly inflated ; equatorial periphery subcircular, distinctly lobate ; axial periphery rounded ; chambers on dorsal side 19, arranged in 3 dextrally coiled whorls ; the initial chambers are small, globigerine, and are followed by slightly larger, roughly globular chambers which increase moderately and regularly in size ; the last whorl is composed of 6 large, roughly globular chambers which are slightly elongated in the direction of coiling and which increase regularly in size up to the fourth chamber and then become gradually smaller ; on the ventral side the 6 roughly globular, strongly inflated chambers increase moderately and regularly in size at first, but after the fourth become smaller ; sutures on the dorsal side curved, depressed in the early part, very slightly curved to almost straight, depressed in the later part ; on the ventral side the sutures are almost straight, radial and strongly incised ; umbilicus wide, deep and open ; aperture interiomarginal, umbilical ; wall calcareous, perforate ; surface distinctly granular, papillose or even nodose, with the nodes tapering out in the form of short, stout, spine-like projections especially along the periphery and around the umbilicus.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·45 mm.
Minimum diameter = 0·34 mm.
Thickness = 0·28 mm. (across the middle part test)

REMARKS. White (1928) noticed that the aperture in *G. mckannai* extends from the umbilicus approximately half way to the peripheral margin. This feature has since made it difficult for authors to decide whether the species is a true *Globigerina* or a *Globorotalia*.

Bolli (1957*b*), followed by Bolli & Cita (1960*b*), Hillebrandt (1962) and Gartner & Hay (1962), removed this species to the genus *Globorotalia*, while Loeblich & Tappan (1957*a*) and Berggren (1960*a*), emphasized the fact that it is a true *Globigerina*, although the aperture in some specimens shows a tendency to extend to a somewhat extraumbilical position. The present study substantiates these observations, and specimens of *G. mckannai* with typical interiomarginal, umbilical apertures were recorded in far greater numbers than forms with a slight tendency towards the development of an extraumbilical aperture. Moreover, the forms described by Bolli (1957*b*) as *Globorotalia mckannai* (White) differ from the holotype in being smaller, higher on the dorsal side and having a much narrower umbilicus. On the other hand, Bolli (pl. 16, figs. 1–3, 10–12) described as *G. gravelli* Brönnimann and as a transitional form between *G. soldadoensis* and *G. gravelli*, forms which are typically *G. mckannai*.

Nakkady (1950) described as *Globigerina cretacea* var. *esnehensis*, a form which is typically *G. mckannai*. Examination of the holotype of Nakkady (B.M.N.H., P.41762) confirms its identity with *G. mckannai*, although the paratypes (B.M.N.H., P.41763) most probably belong to a different species.

Said & Kenawy (1956) quite unjustifiably removed Nakkady's variety to the genus *Rugoglobigerina* and raised it to specific rank. However, these authors did not give any description, and their figures alone cannot be assigned to any known form.

Brönnimann (1952*b*), Bolli (1957*b*) and Hornibrook (1958) described as *Globigerina gravelli* Brönniamnn, forms which conform well with *G. mckannai* White, and thus *G. gravelli* is considered to be a junior synonym.

Loeblich & Tappan (1957*a*) followed by Olsson (1960) described as *Globorotalia strabocella* Loeblich & Tappan, a form which may probably be an extreme variant of *G. mckannai* or a transitional stage between it and *Globorotalia hispidicidaris* Loeblich & Tappan.

Globigerina mckannai White is believed to have evolved from *Globigerina alanwoodi* sp. nov., by the development of the granular, spinose surface. On the other hand, it is believed to have evolved into *Globorotalia hispidicidaris* Loeblich & Tappan by the flattening of the dorsal side and the development of the angular truncate chambers, subacute axial periphery, sharply angled umbilical shoulder and typical extraumbilical-umbilical aperture. Again, it is not excluded that *Globigerina soldadoensis* Brönnimann has also evolved from *G. mckannai* by the reduction in the number of chambers and in the size of test.

Globigerina mckannai White is distinguished by its large, circular, moderately inflated test ; its distinctly granular, nodose, spinose surface ; slightly raised dorsal side and strongly inflated ventral side ; its numerous, subglobular, inflated chambers; short, depressed, radial sutures on both sides ; and wide, deep umbilicus.

HYPOTYPE. P.45580.

HORIZON AND LOCALITY. Figured specimen, from sample No. 51, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was first described from the Velasco formation of Mexico which was wrongly considered by White as Upper Cretaceous. Hay (1960) recorded it from the same formation, ranging throughout the *Globorotalia pseudomenardii* and the *Globorotalia velascoensis* Zones which he considered as Landenian.

Reliable records show that *G. mckannai* White is restricted to the Upper Paleocene and the basal part of the Lower Eocene. All records of this species from rocks older than Upper Paleocene (e.g. Bermudez 1961 ; Nakkady 1959 ; Said & Kenawy 1956) are definitely erroneous, as are records from rocks younger than the Lower Eocene (e.g. Brönnimann 1952*b*).

In the Esna–Idfu region, *G. mckanni* White appears in the upper part of the Upper Paleocene *G. velascoensis* Zone, the *G. aequa*/*G. esnaensis* Subzone. It floods the lower and middle parts of this subzone, then fades out gradually towards the top. In the overlying Lower Eocene, *G. wilcoxensis* Zone, a few forms were observed which only differ from typical *G. mckannai* in having fewer chambers and being much smaller in size. They probably represent the last stage in the development of this species or a transitional stage between it and a possible direct descendant, *G. soldadoensis* Brönnimann.

Globigerina nodosa sp. nov.

(Pl. 15, figs. 6*a–c*)

Diagnosis. A *Globigerina* species with roughly triglobular, compressed test ; nodose, spinose surface ; wide, deep umbilicus ; radial, depressed sutures ; and small last chamber.

Description. Test small, coiled in a low trochospire, roughly triglobular, compressed ; dorsal side weakly convex ; ventral side moderately inflated ; equatorial periphery roughly ovoid, distinctly lobate ; axial periphery rounded ; chambers on the dorsal side appear to be 14 in number ; they are arranged in 3 sinistrally coiled whorls, and increase rapidly in size in the early part and slowly later ; initial chambers small, indistinct and almost masked by the surface rugosity ; the last whorl is composed of 4½ chambers (3½ normal + 1 abortive) : with one exception these are relatively large, roughly ovoid, moderately inflated and slightly compressed ; the abortive chamber is relatively small, roughly ovoid and indistinct ; on the ventral side the chambers are 4½, roughly globular, slightly compressed and increase moderately in size except for the small abortive chamber ; sutures on the dorsal side curved, depressed in the early part, almost straight, radial and depressed later ; on the ventral side they are straight, radial and strongly incised ; umbilicus wide, deep and open ; aperture interiomarginal, umbilical ; wall calcareous, perforate ; surface distinctly papillose or even nodose, with the nodes tapering out in the form of thick stout, spine-like projections especially along the periphery and around the umbilicus.

Dimensions of holotype.

Maximum diameter = 0·40 mm.
Minimum diameter = 0·31 mm.
Thickness = 0·25 mm. (along the middle part of test)

Remarks. This form is rather rare in the samples studied. However, it is quite distinct from all known *Globigerina* species and is therefore described as new despite its rarity.

Globigerina nodosa is distinguished from *G. triloculinoides* Plummer by its non-reticulate, nodose, spinose surface ; its much wider umbilicus ; its compressed test ; and by the lack of the well-developed apertural lip. It is distinguished from *G. inaequispira* Subbotina by its smaller, compressed, non-elongate test, its heavily spinose surface and its much smaller last chamber. The forms described as *Globigerina inaequispira* Subbotina, by Loeblich & Tappan (1957*a*) and by Olsson (1960) are completely different from Subbotina's original description and figures, but may belong to the present species, although they are much more inflated. Similarly the spinose forms described as *G. triloculinoides* Plummer by Shifflett (1948) belong to the present species. *Globigerina chascanona* Loeblich & Tappan has a similar surface texture but is much higher on the dorsal side, has more chambers and a much narrower umblicus. *Globigerina stonei* Weiss has a more inflated test, an almost rectlinear spiral suture, and its surface texture is not as rough as that of the present species.

Globigerina nodosa sp. nov. probably evolved from *G. chascanona* Loeblich & Tappan although no direct evidence was recorded.

HOLOTYPE. P.45581.

PARATYPES. P.45582.

HORIZON AND LOCALITY. Holo- and paratypes, from sample No. 49, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globigerina nodosa* sp. nov. is a rather rare form occuring only in the *G. aequa/G. esnaensis* Subzone of upper Upper Paleocene age.

Globigerina soldadoensis Brönnimann

1952*b* *Globigerina soldadcensis* Brönnimann : 9–11, pl. 1, figs. 1–9.
1953 *Acarinina interposita* Subbotina : 231, pl. 23, figs. 6*a*–7*c*.
1957*b* *Globigerina soldadoensis* Brönnimann ; Bolli (pars) : 71, pl. 16, figs. 7–9, non figs. 10–12.

REMARKS. *Globigerina soldadoensis* Brönnimann is distinguished by its medium sized to large, low trochospiral test ; its granular, heavily papillose, nodose surface ; its 4–5 large roughly quadrangular chambers in the last whorl which are elongated in the direction of coiling ; its straight, radial, strongly depressed sutures on both sides, and its wide umbilicus.

G. soladoensis is very closely related to *G. mckannai* White from which it is believed to have evolved by the reduction in size and in the number of chambers of test. The form described by Bolli (1957*b*, pl. 16, figs. 10–12) as transitional between *G. soladoensis* and *G. gravelli* Brönnimann, is most probably *G. mckannai* White. Bolli stated that *G. soldadoensis* is closely related to *G. primitiva* Finlay ; however, Bolli's *G. primitiva* (pl. 15, figs. 6–8) is actually *G. stonei* Weiss, which may be related to the present species although it is much smaller.

Gartner & Hay (1962) described as *G. soldadoensis* Brönnimann, a form which may belong to *G. esnaensis* (Le Roy) as can be seen from their figures.

HYPOTYPE. P.45583.

HORIZON AND LOCALITY. Hypotype from sample No. 63, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was first described from the Paleocene–Eocene Lizard Springs, Soldado and Navet formations of Trinidad, and was recorded from the same formations by Bolli (1957*b*). It was also recorded from the Paleocene and Lower Eocene of the Caribbean region (Bermudez 1961) and from the " zone of conical *Globorotalias* " of the northern Caucasus, (Subbotina 1953).

In the Esna–Idfu region, *G. soldadoensis* occurs as a rare form in the *G. aequa/G. esnaensis* Subzone of uppermost Paleocene age, and continues in the overlying Lower Eocene *G. wilcoxensis* Zone.

Globigerina spiralis Bolli

(Pl. 16, figs. 2*a–c*)

1957*b* *Globigerina spiralis* Bolli : 70, pl. 16, figs. 16–18.
1960*b* *Globigerina spiralis* Bolli ; Bolli & Cita : 12, pl. 32, figs. 2*a–c*.
1962 *Globigerina spiralis* Bolli : Hillebrandt : 122, pl. 11, figs. 20*a–b*.

Description. Test medium sized, coiled in a relatively high trochospire ; dorsal side highly convex ; ventral side moderately inflated ; equatorial periphery roughly ovoid, lobate ; axial periphery rounded ; chambers on the dorsal side 22 in number, increasing regularly in size and arranged in 4 dextrally coiled whorls ; initial chambers small, inflated, globigerine, slightly compressed, increasing moderately in size and followed by slightly less globular chambers which are moderately elongated in the direction of coiling and increase slowly in size ; the last whorl is composed of 4½ relatively large, crescentic to roughly quadrate chambers which are strongly elongated in the direction of coiling and increase slowly in size ; the 4½ chambers on the ventral side are relatively large, roughly globular, and increase slowly in size ; sutures on the dorsal side short, almost straight, radial and depressed ; on the ventral side they are long, straight, radial and strongly incised ; umbilicus narrow, open, filled with foreign material ; aperture interiomarginal, umbilical, partially covered with the foreign material filling the umbilicus ; wall calcareous, perforate ; surface smooth.

Dimensions of described specimen.

Maximum diameter = 0·34 mm.
Minimum diameter = 0·29 mm.
Thickness = 0·26 mm.

Remarks. *Globigerina spiralis* Bolli is distinguished by its medium to small sized, smooth, highly trochospirally coiled test ; its short, almost straight, depressed dorsal sutures ; and long, straight, depressed, ventral ones ; its chambers which increase slowly in size ; and its narrow umbilicus.

The species is morpholgically similar to both *Globigerina edita* Subbotina and *Globigerina compacta* Hofker. An examination of the holotypes of these forms is needed to establish their relationship.

Loeblich & Tappan (1957*a*) and Olsson (1960) described as *G. spiralis* Bolli, forms with a rough spinose surface. These probably belong to *Globigerina aquiensis* Loeblich & Tappan as suggested by their morphological features and stratigraphical distribution.

G. spiralis Bolli probably evolved from *G. arabica* sp. nov. by a reduction in the size of test and in the number of chambers in the last whorl, by the development of more tightly coiled chambers which are strongly elongated in the direction of coiling, a higher dorsal spire and a much narrower umbilicus. The morpholgical features and stratigraphical distribution of these two species support this proposition, although no direct evidence was recorded. On the other hand, *G. spiralis* probably evolved into *G. haynesi* sp. nov. in the upper Danian time by a reduction in the number of chambers, and in the height of the dorsal spire, by an increase in the rate of growth in the last whorl and by the development of a delicately papillose surface.

HYPOTYPE. P.45584.

HORIZON AND LOCALITY. Figured specimen, from sample No. 53, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globigerina spiralis* was first described from the lower Lizard Springs formation of Trinidad, where it was found to be restricted to the *G. uncinata* Zone. Bolli & Cita (1960*a*, *b*) recorded it from the Paleocene of the Paderno d'Adda section of northern Italy, where they considered its range as Danian. However the stratigraphical range of *G. spiralis* as interpreted from the charts of Bolli (1957*b*) and Bolli & Cita (1960*a*, *b*) is Upper Danian–lower Middle Paleocene.

Hay (1960) recorded *G. spiralis* throughout the Upper Danian *G. uncinata* Subzone of the Velasco formation of Mexico, and Hillebrandt (1962) recorded it throughout the Upper Danian and the overlying Lower, Middle and Upper Paleocene of Austria.

In the Esna–Idfu region, *G. spiralis* appears as a rare to common form in the top part of the Danian ; it increases gradually in number upwards in the section to the basal part of the *G. velascoensis* Zone where it reaches its acme : it then fades out gradually and dies out completely in the lower part of the *G. aequa*/*G. esnaensis* Subzone (uppermost Paleocene).

Globigerina stonei Weiss

(Pl. 16, figs. 1*a*–*d*)

1949 *Globigerina* cf. *pseudobulloides* Plummer ; Cushman & Stone : 57, pl. 10, figs. 15*a*, *b*.
1955*a* *Globigerina stonei* Weiss : 18, pl. 5, figs. 16–21.
1955*b* *Globigerina stonei* Weiss ; Weiss : 308–309, pl. 2, figs. 1–3.
1957*b* *Globigerina primitiva* (Finlay) ; Bolli : 71, pl. 15, figs. 6–8.

DESCRIPTION. Test medium sized, coiled in a low trochospire ; dorsal side slightly convex with the last chambers inflated and the early ones depressed in the form of a sharply cut, slightly sunken, oblong mass ; ventral side strongly inflated ; equatorial periphery roughly ovoid, distinctly lobate ; axial periphery rounded ; chambers on the dorsal side about 9, arranged in 2 sinistrally coiled whorls, increasing moderately in size in the early part and very rapidly later ; initial chambers very small, depressed, tightly coiled and masked by the surface rugosity ; the last whorl is composed of 4 relatively large, subglobular chambers with almost straight inner margins and distinctly curved outer ones ; the first two chambers in the last whorl are roughly quadrangular, elongated in the direction of coiling and slightly inflated, while the last two are roughly globular, much bigger in size and strongly inflated ; on the ventral side the chambers are 4, globular, inflated and rapidly increasing in size ; sutures on both sides straight, radial and strongly incised ; spiral suture angular, rectispiral and strongly depressed ; umbilicus roughly rectangular in outline, relatively wide, deep and open ; aperture interiomarginal, umbilical, a small narrow slit with a delicate apertural lip of which remnants are still preserved ; wall calcareous, perforate ; surface heavily papillose or even nodose.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·33 mm.
Minimum diameter = 0·25 mm.
Thickness = 0·25 mm.

REMARKS. *Globigerina stonei* is distinguished by its small to medium sized, moderately inflated test ; its very small, tightly coiled, depressed early part, and relatively large, strongly inflated chambers which increase rapidly in size in the last whorl, and have almost straight, depressed, inner margins and distinctly curved outer ones ; its radial, depressed sutures on both sides ; its angular, depressed spiral suture, and its papillose or rather nodose surface.

Acarinina triplex Subbotina (1953, pl. 23) includes forms identical with both *G. stonei* (figs. 1, 3, 5) and *G. velascoensis* (figs. 2, 4). However, examination of the holotypes is needed before using the name *G. triplex* for *G. stonei*.

Berggren (1960*a*) removed *Acarinina triplex* Subbotina to *Globigerina* as he noticed that the aperture is interiomarginal, umbilical in position and sometimes extends towards the periphery. He stated that he had compared his specimens of *Globigerina triplex* (Subbotina) from the Lower Eocene of Denmark and northwestern Germany with comparative material in the collection of Dr. N. Subbotina, Leningrad, and found them to be identical. However, his figured forms (pl. 6, figs. 2*a*–3*c*, pl. 13, figs. 1*a*–2*c*) differ from both *Acarinina triplex* Subbotina and *G. stonei* Weiss, in having a higher dorsal side, more spinose surface, and in lacking the straight inner margins of the chambers and the angular spiral suture.

Subbotina (1953) also described as *Globigerina pseudoeocaena* var. *trilobata*, a form which probably belongs to *G. stonei*, although it is much larger.

Bolli (1957*b*) described as *Globigerina primitiva* (Finlay), forms which most probably belong to *G. stonei* Weiss, as can be seen from his figures. *Globoquadrina primitiva* was first described by Finlay (1947) from the Middle Eocene of New Zealand, but was removed to the genus *Globigerina* by Brönnimann (1952*b*). Examination of topotypes of *Globoquadrina primitiva* Finlay kindly sent to the present author by Drs. N. de B. Hornibrook and G. Jenkins of the Geological Survey of New Zealand, showed that it is quite distinct from the present species, although it has a similarly rough surface, a straight, depressed spiral suture and a quadrate appearance. In view of these morphological similarities, it is possible that *G. stonei* evolved into *Globoquadrina primitiva* in Lower Eocene time by the development of the characteristic apertural flaps, the peculiar apertural face of the last chamber and the angularly protruding ventral side. On the other hand, *G. stonei* is believed to have evolved from *G. velascoensis* Cushman in Upper Paleocene time by the development of the rough surface and non-appressed last chamber. Specimens of *G. stonei* with a finely papillose surface are believed to be transitional to *G. velascoensis*, while those with the heavily nodose surface are probably transitional to *G. primitiva*.

Gartner & Hay (1962) described as *G.* cf. *G. inaequispira* Subbotina from the type

Ilerdian of Spain, forms which probably belong to *G. stonei* Weiss, as can be seen from their description.

HYPOTYPE. P.45585.

HORIZON AND LOCALITY. Figured specimen, from sample No. 68, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was first described from the Upper Paleocene, Pale Greda formation of northwestern Peru, and was previously recorded as *G.* cf. *pseudobulloides* from the Lower Eocene Chacra formation of the same area (Cushamn & Stone 1949). On his range chart, Weiss (1955*b*) showed this species to range throughout the Paleocene, Lower Eocene, and the lower part of the Middle Eocene.

It was also recorded under the name *G. primitiva* (Finlay) from the Upper Paleocene–Lower Eocene of the Lizard Springs formation of Trinidad (Bolli, 1957*b*), where it was shown to range from the upper part of the *G. pseudomenardii* Zone to the upper part of the *G. aragonensis* Zone.

In the Esna–Idfu region *G. stonei* Weiss appears in the uppermost Paleocene *G. aequa/G. esnaensis* Subzone. It crosses the Paleocene–Lower Eocene boundary and occurs abundantly in the overlying *G. wilcoxensis* Zone.

Globigerina triloculinoides Plummer

(Pl. 15, figs. 7*a–c*)

1926 *Globigerina triloculinoides* Plummer : 134–135, pl. 8, figs. 10*a–c*.
1937*b* *Globigerina triloculinoides* Plummer ; Glaessner : 382, pl. 4, figs. 33*a–c*.
1940 *Globigerina triloculinoides* Plummer ; Cushman : 72, pl. 12, figs. 15*a*, *b*.
1941 *Globigerina triloculinoides* Plummer ; Toulmin : 607, pl. 82, fig. 3.
1942 *Globigerina triloculinoides* Plummer ; Cushman and Todd : 43, pl. 8, figs. 1, 2.
1943 *Globigerina triloculinoides* Plummer ; Beck : 609, pl. 108, figs. 2, 3.
1944 *Globigerina triloculinoides* Plummer ; Cooper : 353, pl. 54, figs. 12–13.
1952*b* *Globigerina triloculinoides* Plummer ; Brönnimann : 24–25, pl. 3, figs. 13–18.
1952*b* *Globigerina hornibrooki* Brönnimann : 15, pl. 2, figs. 4–6.
1952*b* *Globigerina linaperta* Finlay, Brönnimann : 16, pl. 2, figs. 7–9.
1952*b* *Globigerina finlayi* Brönnimann : 18, pl. 2, figs. 10–12.
1952*b* *Globigerina stainforthi* Brönnimann : 23, pl. 3, figs. 10–12.
1953 *Globigerina triloculinoides* Plummer ; Subbotina : 82, pl. 11, figs. 15*a–c*, pl. 12, figs. 1*a*–2*c*.
1953 *Globigerina trivialis* Subbotina : 64, pl. 4, figs. 4*a*–8*c*.
1955*b* *Globigerina triloculinoides* Plummer ; Weiss : 308, pl. 1, figs. 18, 19 ; non 20, 21.
1955*b* *Globigerina pseudotriloba* White ; Weiss : 308, pl. 1, figs. 11–13.
1955 *Globigerina triloculinoides* Plummer ; Dalbiez & Glintzboeckel (*in* Cuvillier *et al.*) : 534–536, text-figs. 2*a–c*.
1956 *Globigerina triloculinoides* Plummer ; Haynes : 99–100, pl. 17, figs. 15–15*b*, ? 11–11*b*.
1956 *Globigerina pseudotriloba* White ; Said & Kenawy : 157, pl. 7, figs. 25*a*, *b*.
1957*b* *Globigerina triloculinoides* Plummer ; Bolli (pars), 70, pl. 15, figs. 18–20, ? pl. 17, figs. 25, 26.
1957*b* *Globigerina linaperta* Finlay ; Bolli : 70–71, pl. 15, figs. 15–17.
1957*b* *Globigerina triangularis* White ; Bolli : 71, pl. 15, figs. 12–14.

1957*a* *Globigerina triloculinoides* Plummer ; Loeblich & Tappan : 183, pl. 40, figs. 4*a*–*c* ; pl. 41, figs. 2*a*–*c* ; pl. 42, figs. 2*a*–*c*, pl. 43, figs. 5*a*–*c*, 8*a*–9*c* ; pl. 45, figs. 3*a*–*c* ; pl. 46, figs. 1*a*–*c* ; pl. 47, figs. 2*a*–*c* ; pl. 52, figs. 3–7 ; pl. 56, figs. 8*a*–*c* ; pl. 62, figs. 3*a*–4*c*.
1957 *Globigerina triloculinoides* Plummer ; Troelsen : 129, pl. 30, figs. 4*a*–*c*, ? 3*a*–*c*.
1959 *Globigerina triloculinoides* Plummer ; Nakkady (pars) : 461, pl. 3, figs. 5*a*–*c*.
1960 *Globigerina triloculinoides* Plummer ; Olsson : 43, pl. 7, figs. 22–24.
1960 *Globigerina triloculinoides* Plummer ; Bolli & Cita : 13–14, pl. 31, figs. 1*a*–*c*.
1960*g* *Globigerina triloculinoides* Plummer ; Hofker (pars) : 76, figs. 26*a*–28*c*,? 24*a*–*c* ; non figs. 21*a*–*c*, 25*a*–*c*.
1960*i* *Globigerina triloculinoides* Plummer ; Hofker (pars) : 128, pl. 3, figs. 2–4, ? fig. 1.
? 1961 *Globigerina triloculinoides* Plummer ; Said & Kerdany : 336, pl. 1, figs. 9*a*–*c*.
1962 *Globigerina triloculinoides* Plummer, Berggren : 86–88, pl. 14, figs. 1*a*–2*b*.
1962 *Globigerina triloculinoides* Plummer ; Hillebrandt : 119–120, pl. 11, figs. 1*a*–*c*.

DESCRIPTION. Test medium sized, triglobular, slightly compressed ; dorsal side very slightly raised ; ventral side strongly inflated ; equatorial periphery roughly ovoid, tripartite, distinctly lobate ; axial periphery rounded ; chambers on the dorsal side 11, arranged in 3 dextrally coiled whorls ; the initial chambers are very small, inflated, and increase slowly in size to the beginning of the last whorl, where the chambers increase very rapidly in size ; the last whorl thus constituting most of the test, and the last chamber almost half the test ; the last whorl is composed of 3½ large, subglobular chambers ; on the ventral side the chambers are nearly 3½, globular and strongly inflated ; sutures on the dorsal side short, curved, depressed in the early part, and long, depressed, very slightly curved in the later part ; on the ventral side the sutures are strongly depressed, nearly straight and radial ; umbilicus roughly triangular, narrow, shallow and open ; aperture interiomarginal, umbilical, covered by a distinct, prominent lip ; wall calcareous, thin, finely perforate ; surface coarsely pitted.

DIMENSIONS OF DESCRIBED SPECIMEN.
Maximum diameter = 0·45 mm.
Minimum diameter = 0·33 mm.
Thickness = 0·32 mm.

MAIN VARIATION.

1. Chambers 6–12, arranged in 2–3 whorls, dextrally or sinistrally coiled (out of 610 specimens studied, 280 coiled sinistrally).
2. Chambers in the last whorl 3–4, moderately or rapidly increasing in size.
3. The surface reticulation varies from coarse to moderate.
4. The apertural flap varies in size, and the aperture in some specimens tends to extend very slightly outside the umbilicus.

REMARKS. *G. triloculinoides* is distinguished by its small, low trochospiral, globular test ; its tripartite appearance ; distinctly pitted surface ; large, inflated chambers of the last whorl ; narrow, shallow umbilicus ; and well-developed apertural flap. This species also exhibits a wide range of variation. Such variation, which obviously falls within the limits of a single species population was used by Brönnimann (1952*b*) as basis for erecting three new species : *G. finlayi*, *G. hornibrooki* and *G. stainforthi*. He tried to distinguish between each of these forms and

G. triloculinoides, although, as can be seen from his descriptions and figures, they are morphologically similar, occur in the same assemblage and have the same stratigraphical distribution. Moreover Brönnimann (1952*b* : 16–17) described as *G. linaperta* Finlay, forms which are actually *G. triloculinoides* Plummer. *Globigerina linaperta* is a Middle Eocene form which may be a descendant of *G. triloculinoides.*

White (1928) described as *G. bulloides* d'Orbigny, *G. pseudotriloba* White, and *G. triangularis* White, forms which most probably belong to *G. triloculinoides* Plummer.

Bolli (1957*b*) studied samples from the same section of Brönnimann (1952*b*) and examined the holotypes of both White (1928) and Brönnimann (1952*b*). He stated that *Globigerina finlayi*, *G. hornibrooki* and *G. stainforthi* were found to be either exceedingly scarce, or not sufficiently differentiated from existing species to warrant separation. He considered *G. finlayi* Brönnimann a synonym of *G. linaperta* Finlay, and *G. hornibrooki* Brönnimann a synonym of *G. triangularis* White, while he regarded *G. stainforthi* Brönnimann as close to *G. triloculinoides* Plummer. However, Bolli's forms described as *G. triangularis* White and *G. linaperta* Finlay are, most probably, *G. triloculinoides* Plummer.

Loeblich & Tappan (1957*a*) considered *G. stainforthi*, *G. hornibrooki*, *G. finlayi*, *G. triangularis* and *G. pseudotriloba* as synonyms of *G. triloculinoides* Plummer. This conclusion is here substantiated by the study of a large population of *G. triloculinoides* from the Paleocene rocks of the Esna–Idfu region, which shows degrees of variation easily covering the various forms previously described under different names in the present synonymy.

Loeblich & Tappan also considered *Globigerina velascoensis* var. *compressa* White as a synonym of *G. triloculinoides* Plummer, in spite of the fact that Bolli (1957*b* ; 78) had previously considered this species to belong to the genus *Globorotalia* where it became a homonym of *Globorotalia compressa* (Plummer) ; hence he changed its name to *Globorotalia tortiva* Bolli. However, Loeblich & Tappan stated that *Globorotalia toriva* Bolli is completely different from *Globigerina velascoensis* var. *compressa* White. An examination of the holotypes of White and of Bolli is essential to end this conflict.

Subbotina (1953) described as *Globigerina trivialis* n.sp. and *Globigerina eocaenica* Terquem var. *eocaenica* Terquem, forms which most probably belong to *G. triloculinoides* Plummer, as mentioned by Berggren (1962).

Brotzen & Pozaryska (1961) erected a new genus *Subbotina* with *Globigerina triloculinoides* Plummer as type species. However, as stated above, *Subbotina* is here considered a junior synonym of *Globigerina* d'Orbigny.

Hofker (1960*g*, *i*) followed by Berggren (1962) suggested certain trends in the evolutionary development of *G. triloculinoides.* However, as the Lower and Middle Danian are missing in the sections studied it was not possible to follow these trends. Nevertheless, general tendencies towards a reduction in the size of the test and towards an increase in surface reticulation were observed upwards in the section.

· HYPOTYPE. P.45586.

HORIZON AND LOCALITY. Figured specimen, from sample No. 38, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was first described from the basal part of the upper Midway group of Texas, which, according to Loeblich & Tappan (1957*a*), is of Upper Danian age. Plummer (1926 : 135) stated that the species is rare in the lower Midway becoming most common in the basal part of the upper Midway, and that it aids in marking the Cretaceous–Tertiary boundary, as no similar form has been seen in the Cretaceous strata below. In spite of this early precise remark of Plummer, many authors (e.g. Said & Kerdany 1961 ; Hofker 1960*g*, *i* ; Nakkady 1959 ; Khalilov 1948, 1949 ; White, 1928) have recorded *G. triloculinoides* or its synonyms from rocks of Maestrichtian age. Clearly, these authors confused *G. triloculinoides* with the superficially similar Maestrichtian *Rugoglobigerina* forms of the *macrocephala* group.

Troelsen (1957) and Berggren (1960*b*, 1962) recorded *G. triloculinoides* as rare in the lower part of the Middle Danian at its type locality in Denmark, and in southern Scandinavia, becoming more common towards the Upper Danian *Tylocidaris vexilifera* Zone ; they did not record it from the Lower Danian.

Berggren (1962 : 88) added that " it does not seem to occur in the Thanetian glauconites above in southern Scandinavia (unless it be in subsurface sections in Denmark), but its continued development elsewhere in more favourable facies is well documented ".

Haynes (1955, 1956) recorded *G. triloculinoides* from the type Thanetian of England, and it was identified from recently studied Thanetian samples which were kindly given to the present author by Dr. Haynes.

Bolli (1957*b*) recorded *G. triloculinoides* throughout the lower part of the Paleocene lower Lizard Springs formation of Trinidad. However, Bolli's *G. triangularis* White, which he recorded throughout the whole Paleocene, is probably *G. triloculinoides* Plummer.

Loeblich & Tappan (1957*a*), after a study of different Lower Tertiary sections including the type locality of *G. triloculinoides*, showed that it ranges throughout the whole Paleocene, but dies out completely before the basal Eocene.

Hay (1960) recorded *G. triloculinoides* throughout the whole Paleocene Velasco formation of Mexico, it being most abundant in the Lower Paleocene (Danian).

Khalilov (1948, 1949), Subbotina (1953), Gans & Knipscheer (1956), Said (1960) and Küpper (1961) extended the range of *G. triloculinoides* to strata younger than the Paleocene. These authors apparently confused *G. triloculinoides* with its younger descendants.

In the Esna–Idfu region, *G. triloculinoides* Plummer floods the whole Paleocene section from the Upper Danian onwards (the Lower and Middle Danian being missing) and dies out completely at the top of the Upper Paleocene *Globorotalia velascoensis* Zone, and thus is considered one of the best Paleocene index fossils. All reliable references record *G. triloculinoides* from Paleocene strata in various parts of the world.

Globigerina triloculinoides parva subsp. nov.

(Pl. 15, figs. 4*a–c*)

DIAGNOSIS. A *Globigerina triloculinoides* with much smaller, more tightly coiled, compressed test, chambers increasing less rapidly in size and more strongly elongated in direction of coiling.

DESCRIPTION. Test small, coiled in a low trochospire ; dorsal side weakly inflated with the early chambers slightly raised above the level of the last whorl ; ventral side moderately inflated ; equatorial periphery roughly ovoid, moderately lobate ; axial periphery subrounded ; chambers on the dorsal side are not all clear, but appear to be 12 in number, arranged in 2½ dextrally coiled whorls ; initial chambers are very small, closely coiled, indistinct and almost masked by the surface pitting ; the last whorl is composed of 3½, roughly crescentic, narrow chambers which increase moderately in size and are strongly elongated in the direction of coiling ; on the ventral side the chambers are 3½, relatively large, roughly globular, moderately inflated but slightly compressed, especially the last one, and increase so rapidly in size that the last chamber constitutes about half of the test ; sutures on the dorsal side, curved depressed in the early part, almost straight, strongly incised later ; on the ventral side they are straight, radial and strongly depressed ; umbilicus very small, narrow and open, with the last chamber slightly pushed over it ; aperture interiomarginal, umbilical, in the form of a long, narrow slit, with a narrow delicate flap ; wall calcareous, perforate; surface densely pitted.

DIMENSIONS OF HOLOTYPE.

Maximum diameter	=	0·31 mm.
Minimum diameter	=	0·27 mm.
Thickness	=	0·25 mm.

REMARKS. *Globigerina triloculinoides parva* is distinguished from *G. triloculinoides* Plummer, from which it is believed to have evolved, by its much smaller, less lobulate, tightly coiled, slightly compressed test ; its roughly crescentic, narrow chambers which are elongated in the direction of coiling, and which increase less rapidly in size ; by its weakly raised early whorls and slightly compressed last chamber.

Brönnimann (1952*b*) described as *G. hornibrooki* n.sp., a form which appears to be closely related to the present subspecies. However, Loeblich & Tappan (1957*a*) considered *G. hornibrooki* to be a junior synonym of *G. triloculinoides* Plummer, while Bolli (1957*b*) considered it to be a junior synonym of *G. triangularis* White. Indeed *G. triangularis* White appears to be closely related to *G. triloculinoides parva* although it is much larger, but White's description is incomplete and the form figured by Bolli who had examined White's holotype, is most probably *G. triloculinoides* Plummer.

Khalilov (1956) described as *G. triloculinoides* var. *nanus*, a form which only differs from typical *G. triloculinoides* Plummer in its smaller size and slightly deepened septal sutures. Khalilov's form should probably be included within *G. triloculinoides* Plummer, and is believed to be transitional to *G. triloculinoides parva*. It is distinguished from the present subspecies by its triglobular test and strongly inflated last chamber, characteristic of typical *G. triloculinoides* Plummer.

HOLOTYPE. P.45587.

PARATYPES. P.45588.

HORIZON AND LOCALITY. Holo- and paratypes, from sample No. 53, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globigerina triloculinoides parva* appears as a rare form in the Upper Danian *G. compressa*/*G. daubjergensis* Zone and continues as a common form throughout the Middle and Upper Paleocene. It reaches its acme in the upper part of the *G. velascoensis* Zone, and then fades out gradually, dying out completely at the top of this zone. As the Lower and Middle Danian are missing in the sections studied, it is not known whether this subspecies accompanies the central form in the Lower and Middle Danian or not.

Globigerina velascoensis Cushman

(Pl. 16, figs. 3*a*–*d*)

1925 *Globigerina velascoensis* Cushman : 19, pl. 3, figs. 6*a*–*c*.
1926*b* *Globigerina velascoensis* Cushman ; Cushman : 605, pl. 20, fig. 21.
1928 *Globigerina velascoensis* Cushman ; White : 196, pl. 28, figs. 2*a*, *b*.
1953 *Acarinina triplex* Subbotina : 230, pl. 23, figs. 2*a*–*c*, 4*a*–*c* only.
1957*b* *Globigerina velascoensis* Cushman ; Bolli : 71, pl. 15, figs. 9–11.
?1960*b* *Globigerina velascoensis* Cushman ; Bolli & Cita : 14–15, pl. 32, figs. 8*a*–*c*.
1962 *Globigerina velascoensis* Cushman ; Hillebrandt : 120–121, pl. 11, figs. 4*a*, *b*.

DESCRIPTION. Test medium sized, coiled in a low trochospire, moderately inflated, more so on the ventral than on the dorsal side ; equatorial periphery roughly ovoid, distinctly lobate ; axial periphery rounded with the last chamber slightly compressed laterally ; chambers on the dorsal side about 11, tightly arranged in $2\frac{1}{2}$ sinistrally coiled whorls, increasing moderately in size in the early part and very rapidly later ; the proloculus appears to be relatively large, globular, inflated, and is followed by crescentic chambers which become roughly quadrangular, and elongate towards the beginning of the final whorl ; the last whorl is composed of $3\frac{1}{2}$, roughly ovoid, angular chambers, with fairly straight inner margins and distinctly curved outer ones ; the last chamber constitutes about $\frac{1}{3}$ of the test ; on the ventral side the chambers are $3\frac{1}{2}$, roughly globular, strongly inflated and increase very rapidly in size ; sutures on the dorsal side curved, depressed in the early part, almost straight and depressed later ; on the ventral side they are almost straight, radial and strongly depressed ; the spiral suture is curved, depressed in the early part, straight, angular (rectispiral) and strongly depressed later ; umbilicus small, narrow and open ; aperture interiomarginal umbilical, a long narrow slit with a delicate apertural lip of which remnants are still preserved ; wall calcareous, perforate ; surface delicately pitted.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter	=	0·33 mm.
Minimum diameter	=	0·25 mm.
Thickness	=	0·27 mm.

REMARKS. The holotype of *G. velascoensis* was described as being much compressed with the sides very nearly parallel, in contrast to the strongly inflated, biconvex forms here described, but Bolli (1957*b* : 71) stated that Cushman's holotype is a poorly preserved and somewhat deformed specimen. Consequently, it would have been quite justifiable to ignore Cushman's deformed holotype, and give the strongly inflated forms described here a new name. However, as Cushman's deformed holotype still shows clearly the main characteristics of *G. velascoensis* as described by White (1928), Bolli (1957*b*), and as shown in the present study, Cushman's name is here retained.

Subbotina (1953) described as *Acarinina triplex* forms which include both *Globigerina velascoensis* Cushman and *G. stonei* Weiss.

Specimens of *G. velascoensis* from the Esna–Idfu region conform well with those of White (1928) and of Bolli (1957*b*), although the latter described his forms as having a smooth surface and a slightly concave dorsal side.

The species is distinguished by its medium sized, inflated test, its strongly appressed last chamber, its angular, depressed spiral suture and its 3½–4 chambers in the last whorl which increase rapidly in size. It is also characterized by the shape of its later chambers which are roughly oblong, with straight inner margins and distinctly curved outer ones.

Globigerina velascoensis was considered by Bolli (1957*b*) to have evolved from *G. triangularis* White, a probable junior synonym of *G. triloculinoides* Plummer, although no direct evidence was recorded. However, as *G. haynesi* n.sp. was clearly observed to have a tendency towards the development of an angular, depressed spiral suture, a tightly coiled test, almost straight inner margins of the chambers in the last whorl and a finely papillose surface, it may represent the ancestral stock from which *G. velascoensis* evolved. The stratigraphical ranges of the two species are in favour of this proposition, and forms of *G. haynesi* with a flatter dorsal side are considered to be transitional to *G. velascoensis*. On the other hand, *G. velascoensis* is believed to have evolved into *G. stonei* Weiss by the development of the heavily nodose or even spinose surface, the chambers which increase more rapidly in size, the wider umbilicus and the less appressed last chamber. Transitional stages between these two species were recorded and their stratigraphical distribution also strongly substantiates this proposition.

HYPOTYPE. P.45589.

HORIZON AND LOCALITY. Figured specimen, from sample No. 51, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was first described by Cushman (1925) from the Velasco formation of Mexico where its stratigraphical distribution was wrongly stated as Upper Cretaceous. It was also recorded from the same formation by Cushman (1926), White (1928), and Hay (1960) where the latter showed it to range from the Upper Danian *G. uncinata* Subzone throughout the whole of the overlying Landenian, where it becomes a flood form.

Bolli (1957*b*) recorded *G. velascoensis* throughout the *G. pseudomenardii* – *G. velascoensis* Zones of the lower Lizard Springs formation, Trinidad, which are here considered as Upper Paleocene. It was again recorded from the same zones in the Paderno d'Adda section of northern Italy, which Bolli & Cita (1960*a*, *b*) considered to be Upper Montian–Thanetian.

Globigerina velascoensis was also recorded from the Paleocene of Guatemala (Bermudez 1961) and from the Paleocene of Austria (Montian–Landenian–Ilerdian) (Hillebrandt 1962).

Reliable references show that *G. velascoensis* ranges only through the Upper Paleocene. All records of this species from rocks younger than Upper Paleocene, (e.g. Emiliani 1954, who recorded it from the Lower Oligocene of Italy) are either erroneous or of reworked specimens, while all records from older strata (e.g. Hay 1960 and Hillebrandt 1962) are most probably confused with apparently similar *Globigerina* species.

In the Esna–Idfu region, *G. velascoensis* appears in the basal part of the Upper Palecocene *Globorotalia velascoensis* Zone, and continues as a rare to common form to the upper part of this zone, where it dies out completely.

Family **GLOBOROTALIIDAE** Cushman 1927

Subfamily **GLOBOROTALIINAE** Cushman 1927

Genus ***GLOBOROTALIA*** Cushman 1927

Type species. *Pulvinulina menardii* (d'Orbigny) var. *tumida* Brady 1877.

1927*b* *Globorotalia* Cushman : 91 (Type species : *Pulvinulina menardii* (d'Orbigny) var. *tumida* Brady 1877).

1949 *Globorotalia* (*Globorotalia*) Cushman & Bermudez : 28 (Type species : *Pulvinulina menardii* (d'Orbigny) var. *tumida* Brady 1877).

1949 *Globorotalia* (*Truncorotalia*) Cushman & Bermudez : 35 (Type species : *Rotalina truncatulinoides* d'Orbigny 1839).

1949 *Globorotalia* (*Turborotalia*) Cushman & Bermudez : 42 (Type species : *Globorotalia centralis* Cushman & Bermudez 1937).

1953 *Acarinina* Subbotina : 219 (Type species : *Acarinina acarinata* Subbotina 1953).

1957 *Planorotalia* Morozova : 1110 (Type species : *Planulina membranacea* Ehrenberg 1854).

1957 *Planorotalites* Morozova : 1112 (Type species : *Globorotalia pseudoscitula* Glaessner 1937).

1958 *Globorotalia* (*Astrorotalia*) Turnovsky : 81 [Type species : *G.* (*A.*) *stellaria* Turnovsky 1958].

1959 *Globigerina* (*Eoglobigerina*) Morozova : 1115 [Type species : *Globigerina* (*Eoglobigerina*) *eobulloides* Morozova, 1959].

Emended diagnosis. Test free, trochospirally coiled, with relatively wide range of variation in size and shape, globigerine, biconvex or planoconvex ; dorsal side evolute, flat or inflated ; ventral side umbilicate, moderately or strongly protruding ; plane of coiling either horizontal or curved ; equatorial periphery rounded, ovoid, or even angular, weakly or strongly lobate, with or without a single marginal keel which can either be weakly or strongly developed, papillose, nodose, spinose or only thickened and limbate ; axial periphery rounded, subrounded, subacute or acute ; chambers arranged in 2–4 whorls, dextrally or sinistrally coiled ; all chambers seen on dorsal side, only those of last whorl seen on ventral side ; initial chambers generally globular, moderately or strongly inflated ; later ones variable in shape, globular, ovate, lenticular, angular rhomboid or angular conical ; sutures on dorsal side straight or curved, raised or depressed, sometimes thickened, limbate or beaded ; on ventral side sutures generally radial or slightly curved, depressed ; umbilicus varying in shape and size, very small or large, with or without everted umbilical collar and/or high, decorated umbilical shoulders, but always present and open ; aperture interiomarginal, extraumbilical-umbilical, rounded, ovoid or slit-like, sometimes bordered by a lip varying from a narrow rim to a broad flap ; wall calcareous perforate, except for the imperforate keel (where present) ; surface smooth or roughened, papillose, hispid or even spinose.

Discussion. Cushman (1927*b*) described *Globorotalia* as a new genus with *Pulvinulina menardii* (d'Orbigny) var. *tumida* Brady as the type species. Marie (1941) considered *Globorotalia* Cushman to have a single terminal aperture, and thus included forms of *Globorotalia* in which the apertures of the previous chambers remain open into the umbilicus, together with *Globotruncana* Cushman within his genus *Rosalinella* (a junior synonym of *Globotruncana*) despite the marked difference in their apertural characters.

Cushman & Bermudez (1949) divided *Globorotalia* largely on the basis of chamber shape into three subgenera, *Globorotalia* (*Globorotalia*), *G.* (*Truncorotalia*) and *G.* (*Turborotalia*). The first subgenus was characterized by its biconvex, compressed test, angular periphery and small umbilicus ; the second was distinguished by its planoconvex, strongly umbilico-convex test, angular periphery, and peculiarly-shaped apertural face of the last chamber ; the third was separated on the basis of its globular test, rounded periphery and absence of a definite umbilicus. This division of *Globorotalia* was either partly or completely accepted by various authors, in spite of the fact that chamber shape and the dimension of the umbilicus are characters of specific rather than generic or subgeneric importance, and that all gradations between one extreme and the other have been recorded. Banner & Blow (1959) considered *Truncorotalia* to be a junior synonym of *Globorotalia* and *Turborotalia* to be a subgenus of the latter. They distinguished *Globorotalia* (*Globorotalia*) from *Globorotalia* (*Turborotalia*) by the fact that the former has an imperforate peripheral carina, at least in part. Loeblich & Tappan (1964) raised *Turborotalia* to generic rank, distinguishing it mainly on the basis of its non-carinate periphery. However, it can be demonstrated that representatives of *Globorotalia* with a rounded, non-carinate periphery evolve gradually into truncated, non-carinate forms, with an acute periphery. These latter, in turn, evolve into sharply keeled *Globorotalia* through various stages with incipient or partially developed keels. All gradations between each of these forms and the following are documented and show clearly that the division of the present genus into two genera or subgenera (*Globorotalia* and

Turborotalia) on the basis of the presence or absence of keel is not practicable. Species with an acute, non-carinate periphery such as *Globorotalia aequa* Cushman & Renz, *G. angulata angulata* (White), *G. whitei* Weiss, *G. wilcoxensis* Cushman & Ponton, *G. apanthesma* Loeblich & Tappan, *G. hispidicidaris* Loeblich & Tappan, *G. pusilla pusilla* Bolli and *G. uncinata uncinata* Bolli neither fit *Turborotalia* Cushman & Bermudez nor *Globorotalia sensu* Banner & Blow (1959) and Loeblich & Tappan (1964).

Thus, in the present study, the genus *Globorotalia* is considered to include forms with a rounded non-carinate periphery, forms with an acute non-carinate periphery, and others with a marginal keel. The recorded transitional stages between these forms exclude the possibility of splitting the genus into two genera or subgenera, and proves *Turborotalia* and *Truncorotalia* to be junior synonyms of *Globorotalia*. However, while *Globotruncana* is differentiated from *Rugoglobigerina* on the basis of the presence of the keel or keels, no such gradation was recorded between them, although Gandolfi (1955) stated that Globotruncana undergoes a process of globigerinization to evolve into *Rugoglobigerina*. Again, the splitting of *Hedbergella* from *Praeglobotruncana* is based only on the presence of a partially or completely developed keel in the latter genus. However, it is not excluded that non-carinate forms have evolved imperceptibly into carinate ones.

Subbotina (1953) described *Acarinina* as a new genus distinguished by its *Globigerina*-like appearance, which she described as being " well-defined in angular Acarininas and better defined in rounded ones ". She also mentioned that in addition to the angular and rounded Acarininas, " . . . there are the intermediate species of Acarininas, which are a transitional group between *Globotruncana* and *Acarinina* ". In spite of this confusion, her description is identical with that of Cushman & Bermudez (1949) for *Turborotalia*, which is here considered to be a junior synonym of *Globorotalia* Cushman 1927, and hence is *Acarinina* Subbotina. Similarly, *Planorotalia* Morozova 1957 ; *Planorotalites* Morozova 1957, *Globorotalia* (*Astrorotalia*) Turnovsky 1958, and *Globigerina* (*Eoglobigerina*) Morozova 1959 are all junior synonyms of *Globorotalia* Cushman 1927, as their type species conform well with *Globorotalia* as defined by Cushman (1927) and emended in the present study. Loeblich & Tappan (1964) considered *Globigerina* (*Eoglobigerina*) Morozova to be a junior synonym of *Globorotaloides* Bolli 1957. The latter genus, as described by Bolli (1957) and emended by Loeblich & Tappan (1964) includes forms transitional between *Globigerina* and *Globorotalia* and should be included in part in their synonymy. However, the fact that Bolli mentioned that the ultimate chamber normally has a single aperture, though multiple ones may occur, does not permit its inclusion in the synonymy of either *Globorotalia* or *Globigerina* for the time being, although none of his figures showed these multiple apertures.

Globorotalia is distinguished from *Globigerina* d'Orbigny by its extraumbilical aperture, the occasional flattening of its chambers, and the occasional presence of a marginal keel and an umbilical everted collar or shoulder. It is distinguished from *Rugoglobigerina* Brönniman by the above-mentioned characters, as well as by the lack of an umbilical cover-plate and of surface meridional costae. It differs from both *Hedbergella* Brönnimann and Brown and *Praeglobotruncana* Bermudez in lacking umbilical portici ; furthermore *Hedbergella* has no keel, and the keel in *Praeglobotruncana* is much weaker than in sharply keeled *Globorotalia*. It is distinguished from both *Globotruncana* Cushman and *Abathomphalus* Bolli, Loeblich & Tappan by the absence of the umbilical cover-plate, by the occasional presence of a single keel, by its extraumbilical aperture (that of *Globotruncana* is umbilical), and by the fact that it always has a definite open umbilicus however small, whereas the umbilicus in *Abathomphalus* is much reduced and is covered by the tegellum.

EVOLUTIONARY DEVELOPMENT OF *GLOBOROTALIA*

Very little is known about the origin of *Globorotalia* because of the marked faunal break between the Maestrichtian and the Danian. However, it is possible that the genus evolved from the youngest representatives of *Hedbergella* (which disappeared completely at the top of the Maestrichtian) by the reduction of the apertural flaps (the umbilical portici) and by the development of the simple umbilicus. *Globorotalia*, in its turn, evolved into *Globigerina* by the confinement of the aperture to an interiomarginal, umbilical position. On the other hand, it is not impossible that *Rugoglobigerina* evolved into *Globigerina* by the loss of the tegilla and the surface meridional costellae, and that the latter evolved into *Globorotalia* by the development of the extraumbilical, umbilical aperture. Whatever the origin of *Globorotalia*, its earliest representatives are known to have a rounded, non-carinate test, which is generally smooth surfaced. At stratigraphically higher levels, these rounded, smooth forms show two major tendencies in their evolution :

1. A general tendency towards the flattening of the dorsal side, followed by the gradual development of a marginal keel through various intermediate stages.
2. A general tendency towards increasing the surface rugosity.

These two tendencies develop either separately or in combination, with the result that the early Paleocene rounded, smooth globorotalias evolve gradually into forms with truncated, non-keeled and/or slightly rougher tests which in turn, evolve into the truncated, sharply-keeled and/or very rugose forms which characterize the Upper Paleocene in various parts of the world. In the Lower Eocene, a new tendency towards reduction in the size of test and increase in the surface rugosity is observed. The result is that most of the Lower Eocene forms are smaller than the Paleocene ones and/or have an extremely rough surface. These tendencies are clearly documented in the present study, and are demonstrated by several lineages, summarized on Text-fig. 15.

Globorotalia acuta Toulmin

(Pl. 19, figs. 5*a*–*c* ; Pl. 20, figs. 1*a*–*d*)

1941 *Globorotalia wilcoxensis* Cushman & Ponton var. *acuta* Toulmin : 608, pl. 82, figs. 6–8.

1942 *Globorotalia wilcoxensis* Cushman & Ponton var. *acuta* Toulmin ; Cushman & Renz : 12, pl. 3, figs. 2*a*–*c*.

1957*a* *Globorotalia acuta* Toulmin ; Loeblich & Tappan : 185–186, pl. 47, figs. 5*a*–*c* ; pl. 55, figs. 4*a*–5*c* ; pl. 58, figs. 5*a*–*c*.

Description. (Specimen, Pl. 20, figs. 1*a–d*.) Test medium-sized, planoconvex, umbilico-convex, coiled in a very low trochospire ; dorsal side flat ; ventral side distinctly protruding with a high umbilical shoulder and a rough, beaded umbilical flange ; equatorial periphery roughly ovoid, weakly lobate, with a well-developed, beaded keel ; axial periphery sharply acute ; the chambers on the dorsal side increase rapidly in size ; they are about 11 in number, arranged in 2 sinistrally coiled whorls ; the initial chambers are small, indistinct and almost masked by the surface rugosity ; the last whorl is composed of 5 relatively large, roughly crescentic chambers ; those on the ventral side are large, strongly angular conical and increase rapidly in size ; their distal ends taper out and are crowned with a papillose umbilical collar ; sutures on the dorsal side distinct, flush with the surface, oblique and directed sharply backwards ; on the ventral side they are radial and strongly incised ; umbilicus conical in shape, very wide at its top, narrow at the bottom, deep, open and surrounded by a heavily beaded collar ; aperture interiomarginal, extra-umbilical-umbilical, a long, wide arch extending to the periphery with a distinctly developed apertural lip ; wall calcareous, perforate ; surface delicately papillose on the dorsal side, more distinctly so on the ventral, and heavily papillose in the umbilical collar and the marginal keel, with the papillae sometimes tapering out in the form of spine-like projections.

Dimensions of described specimen.

Maximum diameter = 0·44 mm.
Minimum diameter = 0·32 mm.
Thickness = 0·25 mm.

Remarks. The species was first described by Toulmin (1941) as a variety of *G. wilcoxensis* Cushman & Ponton. Cushman & Bermudez (1949) considered this form to belong to their subgenus *Truncorotalia* but retained it as a variety of *G. wilcoxensis*.

Grimsdale (1951), followed by Hamilton (1953) and Graham & Classen (1955) realizing that Toulmin's variety is unrelated to *G. wilcoxensis*, but is morphologically very similar to *G. velascoensis* (Cushman), changed its name to *G. velascoensis* (Cushman) var. *acuta* Toulmin.

Haynes (1955, 1956) described as *G. velascoensis* (Cushman) aff. var. *acuta* Toulmin, a form which is actually a reworked Upper Cretaceous *Globotruncana* species redeposited in the type Thanetian.

Dalbiez & Glintzboeckel (1955) raised Toulmin's variety to specific rank and included it in *Truncorotalia*, a junior synonym of *Globorotalia*, as mentioned above.

Bolli (1957*b*) and Hillebrandt (1962) considered Toulmin's form to be a junior synonym of *G. velascoensis* (Cushman), while Loeblich & Tappan (1957*a*) considered the two species separately. In the Esna-Idfu region, where the two forms are extremely well developed, their morphological characters warrant their separation.

Globorotalia acuta Toulmin is distinguished from *G. velascoensis velascoensis* (Cushman) by its much smaller test, tighter coiling, chambers which increase more rapidly in size and are fewer both in total number and in number in the last whorl :

by its rough surface, less pronounced marginal keel and umbilical collar, flush dorsal sutures and much wider, inward tapering, funnel shaped umbilicus.

Berggren (1960*d* : 99) considered *G. lensiformis* Subbotina to be a junior synonym of *G. acuta* Toulmin. However, the present study showed that the two forms are quite distinct. *G. lensiformis* is distinguished by its extremely narrow umbilicus, while *G. acuta* has an extremely wide umbilicus with a large, beaded umbilical collar.

Aubert (1963) described as *G. acuta* Toulmin, from the Paleocene of Western Morocco, a form which most probably belongs to *G. velascoensis parva* Rey.

Globorotalia acuta has possibly evolved from *G. angulata angulata* (White) or *G. angulata abundocamerata* Bolli, although no direct evidence was recorded.

HYPOTYPES. P.45590–91.

HORIZON AND LOCALITY. Figured specimens, from sample No. 40, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was first described by Toulmin (1941) from the Salt Mountain limestones of Alabama which he considered as Lower Eocene, but was proved by Loeblich & Tappan (1957*a*) to be of Upper Paleocene age. It was also recorded from the Paleocene Soldado formation of Trinidad (Cushman & Renz 1942) ; from the various Paleocene formations of the Gulf and Atlantic Coastal Plains (Cushman 1944 ; Shifflett 1948 and Loeblich & Tappan 1957 *a, b*) ; from the Paleocene of Cuba (Cushman & Bermudez 1948, 1949 ; Bermudez 1950) ; from what was considered as Lower Eocene of Mexico, Carribbean region and the Middle East (Grimsdale 1951) ; from the Mid-Pacific seamounts (Hamilton 1953) ; from the Cretaceous–Tertiary passage beds of Morocco (Rey and Lys in Cuvillier *et al.*, 1955) ; from the so-called Montian–Thanetian of Algeria (Magné & Sigal, *ibid.*) ; from the *Truncorotalia* Zone of the Cretaceous–Tertiary passage beds of Tunisia (Dalbiez & Glintzboeckel, *ibid.*) ; from the Paleocene of Lebanon (Lys & Renouard, *ibid.*) ; from the Velasco formation of Mexico (Loeblich & Tappan, 1957*a, b* ; Bermudez 1961) and from the Upper Paleocene Jicara formation of Puerto Rico (Pessagno 1960).

In the Esna–Idfu region *G. acuta* floods the *G. velascoensis* Zone of Upper Paleocene age, starting at its base and dying out completely at its top.

Globorotalia aequa Cushman & Renz

(Pl. 21, figs. 4*a–c*)

1942 *Globorotalia crassata* (Cushman) var. *aequa* Cushman & Renz : 12, pl. 3, figs. 3*a–c*.
1946 *Globorotalia lacerti* Cushman & Renz : 47, pl. 8, figs. 11–12.
1947 *Globorotalia crassata* (Cushman) ; Subbotina : 119–121, pl. 5, figs. 31–33, pl. 9, figs. 15–17.
1953 *Globorotalia crassata* (Cushman) ; Subbotina (pars) : 211, pl. 17, figs. 11*a*–12*c*, ? figs. 7*a*–10*c*, non figs. 13*a–c*.
1955 *Truncorotalia crassata* var. *aeqgua* (Cushman & Renz) ; Dalbiez & Glintzboeckel (in Cuvillier *et al.*, 1955) : 533, pl. 2, figs. 9*a–c*.
1956 *Globorotalia praenartanensis* Sjutskaya : 98, pl. 3, figs. 5*a–c*.
1957*b* *Globorotalia aequa* Cushman & Renz ; Bolli (pars) : 74–75, pl. 17, figs. 1–3, ? pl. 18, figs. 13–15.

1957 *Globorotalia crassata* var. *aequa* Cushman & Renz ; Sacal & Debourle : 64, pl. 29, figs. 10–12.
1960*b* *Globorotalia aequa* Cushman & Renz ; Bolli & Cita : 17–18, pl. 31, figs. 5*a–c*.
? 1962 *Globorotalia aequa* Cushman & Renz ; Gartner & Hay : 560–561, pl. 2, figs. 1*a*–2*b*.

DESCRIPTION. Test large, coiled in a very low trochospire, strongly umbilico-convex ; dorsal side almost flat, slightly imbricate, with the early whorls slightly more elevated than the last one ; ventral side highly convex and strongly protruding ; equatorial periphery ovoid, distinctly lobate and roughly serrate ; axial periphery acute with the marginal serrations simulating a faintly developed nodose keel ; chambers on the dorsal side 11, arranged in 3 dextrally coiled whorls ; initial chambers very small, slightly inflated, globigerine, increasing very slowly in size, and masked by the surface rugosity ; the last whorl is composed of 3½, large, crescentic chambers which increase very rapidly in size, the last chamber thus constituting about one third of the test ; on the ventral side the chambers are 3½, large, strongly inflated and distinctly protruding ; sutures on the dorsal side strongly curved, slightly depressed ; on the ventral side they are radial, strongly depressed ; umbilicus roughly rectangular, narrow, deep and open ; aperture interiomarginal, extra-umbilical-umbilical, a long, roughly crescentic, wide arch, extending to the periphery; wall calcareous, perforate ; surface highly roughened by long stout, spine-like projections or granules, the roughness decreasing gradually towards the last chamber.

DIMENSIONS OF DESCRIBED SPECIMEN.
Maximum diameter = 0·48 mm.
Minimum diameter = 0·34 mm.
Thickness = 0·30 mm.

MAIN VARIATION.
1. Chambers 9–12, arranged in 2½–3 whorls predominantly dextrally coiled (of 154 specimens chosen at random, 3 coiled sinistrally).
2. The last whorl is composed of 3–4 chambers (usually 3½) which increase very rapidly in size.

REMARKS. *Globorotalia aequa* was first described by Cushman & Renz (1942) as a variety of *G. crassata* (Cushman) ; these authors briefly stated " Variety differing from the typical in the much smoother surface, and the chambers, especially the later ones, broader and more arcuate ". However, from their figures, it is clearly seen that the form has a rough surface and a distinctly spinose periphery.

Bolli (1957*b* : 75) stated that " No close morphologic or stratigraphic connection is evident between *Globorotalia aequa* Cushman & Renz and the coarsely spinose *G. crassata* (Cushman) from the middle to upper Eocene ", and thus he raised this variety of Cushman & Renz to specific rank. He added, " A comparison of the holotypes of *G. aequa* and *G. lacerti* Cushman & Renz clearly indicates that the latter is a junior synonym ". The author is in entire agreement with Bolli's observations, although it has to be clearly stated that *G. aequa* is characterized by its rough, coarsely spinose, nodose surface, contrary to the impression given by Bolli's statement and by that of Cushman & Rentz (1942). Again *G. aequa* is charaterized by its curved, depressed, dorsal sutures, which were vaguely described by Renz (1951) as rather well-pronounced dorsal sutures.

Nakkady (1951*a*) described as *Globorotalia colligera* (Schwager), forms which most probably belong to *G. aequa* as examination of his specimens (B.M.N.H., P.41766) has revealed.

Subbotina (1947, 1953) described as *G. crassata* (Cushman) forms which are actually *G. aequa* Cushman & Renz.

Sjutskaya (1956) described as *Globorotalia praenartanensis* sp. nov., a form which appears to be identical with *G. aequa* and is thus considered to be a junior synonym.

Said & Kenawy (1956) described as *Truncorotalia crassata aequa*, forms which are not related to this species, but which probably belong to *G. aragonensis* Nuttall as can be seen from their figures.

Loeblich & Tappan (1957*a*) described as *G. aequa*, forms with a marginal keel, although *G. aequa* has no keel. These forms most probably belong to *G. quetra* Bolli, *G. loeblichi* sp. nov. and to other undescribed forms.

The form described by Olsson (1960) as *G. aequa* is apparently *G. angulata angulata* (White) and that described by Küpper (1961) as *G.* (*Truncorotalia*) *aequa*, may be transitional to *G. angulata angulata* (White).

Hillebrandt (1962) considered *G. aequa* as a group of three distinct subspecies, namely :

Globorotalia (*Truncorotalia*) *aequa aequa* Cushman & Renz.
Globorotalia (*Truncorotalia*) *aequa simulatilis* (Schwager).
Globorotalia (*Truncorotalia*) *aequa marginodentata* (Subbotina).

He also considered both *G. rex* Martin and *G. kolchidica* Morozova to be junior synonyms of *G. simulatilis* (Shwager), and *G. formosa gracilis* Bolli to be a junior synonym of *G. marginodentata* Subbotina, and then regarded both *G. simulatilis* and *G. marginodentata* to be two distinct subspecies of his *Globorotalia* (*Truncorotalia*) *aequa* group. However, Berggren (1960*a* : 58) stated that " *G. subbotinae* Morozova, may be the correct name for *G. marginodentata* Subbotina if the two species should prove to be synonymous. Illustrations and descriptions in several Russian papers appear to indicate their identity, although a resemblance of *G. subbotinae* to *G. wilcoxensis* is also noted in some cases. A study of type material has shown *Globorotalia marginodentata* Subbotina to be a synonym of *G. rex* Martin." In other words, it is understood from Berggren's statement that both *G. marginodentata* Subbotina and *G. rex* Martin are possibly junior synonyms of *G. subbotinae* Morozova, but the brief description of the latter species does not allow any decision. Until this confusion is cleared up by examination of the holotypes of *Globorotalia simulatilis* (Schwager), *G. subbotinae* Morozova, *G. rex* Martin, *G. marginodentata* Subbotina, *G. formosa gracilis* Bolli and *G. kolchidica* Morozova, it is best to keep *Globorotalia aequa* Cushman & Renz as a separate species.

Globorotalia aequa Cushman & Renz is distinguished by its large, strongly umbilico-convex test ; its distinctly lobate, serrate periphery ; its small number of chambers which increase very rapidly in size in the last whorl, and its last chamber which usually constitutes about one third of the test ; its curved, depressed, dorsal sutures, and radial strongly depressed ventral ones ; its large, crescentic aperture ; and its granular spinose surface.

The species is believed to have evolved from *Globorotalia angulata angulata* (White) in Upper Paleocene time by the increase in the surface rugosity, in the size of test and in the rate of chamber growth. All transitional stages between these two species were recorded in the lower part of the Upper Paleocene *G. velascoensis* Zone of the Esna–Idfu region. On the other hand, *G. aequa* is believed to have evolved into *G. loeblichi* sp. nov. by a reduction in the size of test and in the surface rugosity ; by the development of a distinct, finely beaded keel, a delicately papillose surface and a narrower umbilicus.

HYPOTYPE. P.45592.

HORIZON AND LOCALITY. Figured specimen, from Sample No. 55, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was first recorded from the Paleocene Soldado formation of Trinidad which was described by Cushman & Renz (1942) as " Eocene, Midway, Soldado formation . . . . . ".

Bolli (1957*b*) and Loeblich & Tappan (1957*a*) reported this species from the Upper Paleocene–Lower Eocene of the Lizard Springs formation of Trinidad, and of the Gulf and Atlantic Coastal plains of the U.S.A. respectively.

All reliable references show that *G. aequa* is an excellent index fossil for the Upper Paleocene in most parts of the world.

In the Esna–Idfu region, *Globorotalia aequa* floods the upper part of the *G. velascoensis* Zone, characterizing together with *G. esnaensis* the *G. aequa*/*G. esnaensis* Subzone, of uppermost Paleocene age. It crosses the Paleocene–Lower Eocene boundary and occurs as a rare form with a much smaller test and a rougher surface in the overlying *G. wilcoxeniss* Zone.

Globorotalia africana sp. nov.

(Pl. 23, figs. 4*a*–*c*)

DIAGNOSIS. A *Globorotalia* with small, concavo-convex, compressed test ; spinose surface ; small, globular, raised early chambers and compressed lenticular later ones ; very large last chamber ; acute axial periphery and partially developed pseudo-keel.

DESCRIPTION. Test small, concavo-convex, compressed and coiled in a low trochospire ; dorsal side gently convex with the early chambers slightly raised above the circumambient last whorl ; ventral side gently concave although the chambers are inflated ; equatorial periphery ovoid, elongate, distinctly lobate and spinose ; axial periphery acute with a partially developed pseudo-keel on the last chamber ; on the dorsal side the chambers are 16, arranged in 3 dextrally coiled whorls ; the initial chambers increase slowly in size, are extremely small, globular, inflated, almost indistinct, and are followed by relatively larger, globular, inflated chambers which increase moderately in size ; the last whorl is composed of 6 relatively large chambers which are globular in the early part, becoming gradually more compressed towards the last chamber, which is roughly lenticular and constitutes more than one-third of the test ; the 6 chambers on the ventral side increase moderately in size (except for the last) and are roughly lenticular, slightly inflated, and compressed ; sutures on the dorsal side short. very gently curved to almost straight, depressed ; on the ventral side they are relatively long, straight, radial and strongly incised ; umbilicus small, shallow and open ; aperture interiomarginal, extraumbilical-umbilical, a low arch with a small, delicate lip ; wall calcareous, perforate ; surface delicately spinose especially along the periphery.

DIMENSIONS OF HOLOTYPE.

Maximum diameter	=	0·30 mm.
Minimum diameter	=	0·20 mm.
Thickness	=	0·14 mm. (of last chamber)

REMARKS. *Globorotalia africana* sp. nov. is distinguished from the closely related *G. sibaîyaensis* sp. nov. by its concavo-convex test, numerous chambers, acute axial periphery, partially developed pseudo-keel, raised, globular early chambers and compressed lenticular later ones.

The only known Paleocene *Globorotalia* species with a gently curved plane of coiling along which the test grows in such a way as to produce a shallow concavo-convex form, is *Globorotalia kilabiyaensis* sp. nov. from the underlying Danian rocks. This species may represent the ancestral stock from which *G. africana* evolved, although *G. kilabiyaensis* was not recorded from rocks younger than Upper Danian, while *G. africana* was only recorded from the uppermost Paleocene.

HOLOTYPE. P.45593.

HORIZON AND LOCALITY. Holotype from sample No. 50, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species is a rare form in the *G. aequa–G. esnaensis* Subzone of uppermost Paleocene age.

Globorotalia angulata abundocamerata Bolli

(Pl. 22, figs. 2*a–c*)

? 1947 *Globorotalia conicotruncata* Subbotina (pars) : 115, pl. 4, figs. 11–13 ; pl. 9, figs. 9–11.
? 1949 *Globorotalia (Truncorotalia) velascoensis* (Cushman) ; Cushman & Bermudez : 41, pl. 8, figs. 4–6
? 1951*a* *Globorotalia velascoensis* (Cushman) ; Nakkady : 54, pl. 1, fig. 6.
1953 *Acarinina conicotruncata* (Subbotina) Subbotina (pars) : 220–222, pl. 20, figs. 5*a*–9*c*, non figs. 10*a*–12*c*.
? 1956 *Globorotalia angulata* White var. *Kubanensis* Sjutskaya : 93–94, pl. 3, figs. 4*a–c*.
? 1957*a* *Globorotalia trichotrocha* Loeblich & Tappan : 195, pl. 50, figs. 5*a–c* ; pl. 57, figs. 1*a*–2*c*.
1957*a* *Globorotalia apanthesma* Loeblich & Tappan (pars) : 187–188, pl. 55, figs. 1*a–c* only. Non pl. 48, figs. 1*a–c* ; pl. 58, figs. 4*a–c* ; pl. 59, figs. 1*a–c*.
1957*b* *Globorotalia angulata abundocamerata* Bolli : 74, pl. 17, figs. 4–6.
? 1959 *Globorotalia velascoensis* (Cushman) ; Nakkady : 462, pl. 4, figs. 4*a–c*.
1960*b* *Globorotalia angulata abundocamerata* Bolli ; Bolli & Cita : 19–20, pl. 33, figs. 6*a–c*.

? 1961 *Globorotalia convexa* Subbotina ; Said & Kerdany : 329, pl. 1, figs. 7*a–c*.
1962 *Globorotalia* (*Truncorotalia*) *angulata* (White) ; Hillebrandt : 131–132, pl. 13, figs. 14*a*–15*c*.

Description. Test large, planoconvex, umbilico-convex, coiled in a very low trochospire; dorsal side almost flat and very slightly imbricate; ventral side distinctly convex and strongly protruding ; equatorial periphery circular, slightly lobate ; axial periphery subacute, with a faint, delicately beaded keel in the early part which fades out gradually towards the last chamber ; the 17 chambers on the dorsal side increase slowly in size and are arranged in 2½ sinistrally coiled whorls ; the initial chambers are small, very slightly inflated, globigerine, and are followed by closely coiled crescentic chambers ; the last whorl is composed of 7 chambers which enlarge so slowly that they appear to be roughly equal in size ; the 7 chambers on the ventral side are relatively large, strongly inflated, roughly conical, distinctly angular and strongly truncate laterally ; sutures on the dorsal side curved, slightly depressed, on the ventral side radial, strongly depressed ; umbilicus relatively narrow, deep and open ; aperture a narrow slit, interiomarginal, extraumbilical-umbilical ; wall calcareous perforate; surface finely pitted, with the ridges between the pits simulating stout spine-like projections covering the surface, especially on the ventral side, and thus the test appears as if it is granular or subspinose.

Dimensions of described specimen.

Maximum diameter	=	0·41 mm.
Minimum diameter	=	0·37 mm.
Thickness	=	0·25 mm.

Main variation.

1. Chambers 14–18, arranged in 2–3½ whorls, generally sinistrally coiled, but dextral forms also occur (of 40 specimens chosen at random, 26 coiled sinistrally).
2. Chambers in the last whorl 6–7.

Remarks. *Globorotalia angulata abundocamerata* was first described by Bolli (1957*b*) as a new subspecies to distinguish the multi-chambered forms of *Globorotalia angulata* from the form with few chambers originally described by White (1928).

Subbotina (1947, 1953) described as *Globorotalia conicotruncata* and *Acarinina conicotruncata* respectively, forms which most probably belong to both *G. angulata abundocamerata* and *G. angulata angulata*. However, examination of the holotype of *G. conicotruncata* Subbotina is needed before using her name for the present subspecies.

Sjutskaya (1956) described as *Globorotalia angulata* (White) var. *kubanensis* a form which probably belongs to the present subspecies. However, as her description was very brief, Bolli's name is used here. If Sjutskaya's varietal name is later proved to be a senior synonym it should be raised to subspecific rank as warranted by its morphological features and stratigraphical range. Again, comparison with the holotype of *G. conicotruncata* Subbotina may prove both Sjutkaya's variety and the present subspecies to be junior synonyms of *G. conicotruncata*. In its turn the latter species should be considered as a subspecies of *G. angulata* (White) and therefore its name should be *G. angulata conicotruncata* Subbotina.

Said & Kerdnay (1961, pl. 7, figs. 13*a–c*) described as *G. angulata abundocamerata* Bolli, a form which is completely different from Bolli's original description and figures. On the other hand, these authors described as *Globorotalia convexa* Subbotina, forms which most probably belong to *G. angulata abundocamerata*.

The form, described as *G. conicotruncata* Subbotina by Said (1960) from the Lower Eocene Thebes limestone formation of Luxor, Egypt, is neither related to the form described by Subbotina nor to the present subspecies.

Globorotalia angulata abundocamerata is distinguished by its large, circular umbilico-convex test ; its 6–7 chambers in the last whorl, which increase very slowly in size ; its curved, depressed dorsal sutures, and radial, strongly incised ventral ones; its small, deep umbilicus ; and partially developed keel. Some of the 6-chambered forms described as *G. angulata* (White) by various authors, probably belong to this subspecies.

Globorotalia angulata abundocamerata is believed to have evolved from *G. angulata angulata* (White), and into *G. velascoensis velascoensis* (Cushman) as suggested by their morphological features and stratigraphical ranges. However, it is not excluded that *G. angulata abundocamerata* also evolved into *G. apanthesma* Loeblich & Tappan by the development of the highly rugose surface.

HYPOTYPE. P.45594.

HORIZON AND LOCALITY. Figured specimen, from sample No. 39, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *G. angulata abundocamerata* was first described from the Paleocene lower Lizard Springs formation of Trinidad (Bolli 1957*b*). It was also recorded from the Paleocene of northern Italy (Bolli & Cita 1960*a*, *b*) where its range was wrongly considered as Danian–Lower Montian, although the rest of the planktonic Foraminifera indicated a Middle–basal Upper Paleocene age. Subbotina (1953) recorded her *Acarinina conicotruncata* which is partly synonymous with this subspecies, from the zone of the Danian Foraminifera which Berggren (1960*d*), quite justifiably, regards as belonging somewhere between the Middle and the top of the Paleocene.

Sjutskaya (1956) considered *G. angulata* and its two varieties—*praepentacamerata* and *kubanensis* as the index forms of the Paleocene in the Sub-Caucasus.

G. angulata abundocamerata was also described as *G. velascoensis* from the so-called Danian of the Kharga Oasis, Egypt, which is actually Middle Paleocene (Nakkady 1959), and as *G. convexa* from the so-called Landenian of the Farafra Oasis, Egypt (Said & Kerdany 1961).

Most of the *G. angulata* (White) records probably included in part the present subspecies.

In the Esna–Idfu region, *G. angulata abundocamerata* appears as a common to a flood form slightly higher in the section than the first appearance of *G. angulata angulata* and then decreases gradually, dying out in the basal part of the *G. velasco-*

ensis Zone. Although one specimen, probably referable to this subspecies, was found in the uppermost part of the *G. velascoensis* Zone, this subspecies is still considered to be mainly restricted to the upper part of the Middle Paleocene.

Globorotalia angulata angulata (White)

(Pl. 22, figs. 1*a–c*)

1928*a* *Globigerina angulata* White : 191–192, pl. 27, figs. 13*a–c*.
1937*b* *Globorotalia angulata* (White) Glaessner (pars) : 383, pl. 4, figs. 35, 37, non fig. 36.
1947 *Globorotalia conicotruncata* Subbotina (pars) : 115, pl. 4, figs. 11–13 ; pl. 9, figs. 9–11.
1953 *Acarinina conicotruncata* (Subbotina) Subbotina (pars) : 220–222, pl. 20, figs. 10*a–c*, 12*a–c*, ? 11*a–c*, non figs. 5*a*–9*c*.
1955 *Truncorotalia angulata* (White) ; Dalbiez & Glintzboeckel (in Cuvillier *et al.*, 1955) : 533, 534, pl. 1, figs. 5*a–c*.
1956 *Globorotalia angulata* (White) ; Sjutskaya : 92–93, pl. 3, figs. 2*a–c*.
1956 *Globorotalia angulata* (White) var. *praepentacamerata* Sjutskaya ; 94–95, pl. 3, figs. 3*a–c*.
1957*b* *Globorotalia angulata* (White) ; Bolli : 74, pl. 17, figs. 7–9.
1957*a* *Globorotalia angulata* (White), Loeblich & Tappan (pars) : 187, pl. 48, figs. 2*a–c* ; pl. 55, figs. 2*a–c*, 6*a–c*, 7*a–c* ; pl. 58, figs. 2*a–c* ; pl. 64, figs. 5*a–c* ; non pl. 45, figs. 7*a–c*, and pl. 50, figs. 4*a–c*.
? 1957*a* *Globorotalia apanthesma* Loeblich & Tappan : 187, pl. 48, figs. 1*a–c*.
? 1959 *Globorotalia quadrata* Nakkady & Talaat ; *in* Nakkady : 462, pl. 7, figs. 3*a–c*.
1960 *Globorotalia angulata* (White) ; Olsson : 44, pl. 8, figs. 14–16.
1960*b* *Globorotalia angulata* (White) ; Bolli & Cita : 18–19, pl. 33, figs. 8*a–c*.
1962 *Globorotalia angulata* (White) ; Gartner & Hay : 559–560, pl. 1, figs. 6*a–c*.

DESCRIPTION. Test medium sized, planoconvex, umbilico-convex, coiled in a very low trochospire ; dorsal side almost flat or very slightly inflated, with an imbricate appearance ; ventral side distinctly convex and strongly protruding ; equatorial periphery roughly quadrangular and distinctly lobate ; axial periphery subacute with a few stout, spine-like projections but without keel ; chambers on the dorsal side 15, arranged in 3, dextrally coiled whorls ; the initial chambers are small, slightly inflated, roughly globigerine, and increase slowly and regularly in size till the beginning of the second whorl where they start to enlarge rapidly and become roughly crescentic ; the last whorl is composed of $4\frac{3}{4}$, large, slightly inflated chambers, the last of which is smaller than the penultimate ; on the ventral side the chambers are $4\frac{1}{2}$, large, strongly inflated, distinctly angular and strongly truncate laterally ; sutures on the dorsal side strongly curved, depressed ; on the ventral side, they are straight, radial, strongly incised ; umbilicus roughly rectangular in outline, exceedingly small, deep and open ; aperture a long, narrow slit, interiomarginal, extraumbilical-umbilical with a delicate, narrow lip ; wall calcareous, finely perforate, surface granular or rather pitted.

DIMENSIONS OF DESCRIBED SPECIMEN.
Maximum diameter = 0·390 mm.
Minimum diameter = 0·290 mm.
Thickness = 0·250 mm.

MAIN VARIATION.

1. Chambers 12–15, arranged in $2\frac{1}{2}$–3 whorls generally sinistrally coiled (of 510 specimens studied, 80 coiled dextrally).
2. Chambers in the last whorl 4–5 ; $4\frac{1}{2}$ is most common, but specimens with 5–6 chambers also occur and are considered transitional to *G. angulata abundocamerata*. The last chamber is in most cases smaller than the penultimate.
3. The surface may be moderately or strongly roughened, especially on the ventral side and along the periphery.

REMARKS. The present subspecies was first described by White (1928) as *Globigerina angulata*. Glaessner (1937*b*) removed it from *Globigerina* to *Globorotalia* because of the truncata, angular shape of its chambers. Dalbiez & Glintzboeckel (in Cuvillier *et al.* 1955) and Hillebrandt (1962) considered this species to belong to *Truncorotalia*, while Bermudez (1961) considered it to belong to *Pseudogloborotalia*. Bolli (1957*b*), Loeblich & Tappan (1957*a*), Olsson (1960) and Bolli & Cita (1960*b*), considered the species to belong to the genus *Globorotalia*.

Loeblich & Tappan (1957*a*) apparently confused *G. angulata* White with forms which probably belong to *Globorotalia occlusa* Loeblich & Tappan (see synonymy).

Nakkady (1959) described as *G. angulata* (White) a form which is completely different from White's original description and figures. However, Nakkady & Talaat (*in* Nakkady 1959) described as *Globorotalia quadrata* n.sp., a form which is probably *G. angulata angulata* (White).

Grimsdale (1951) stated that *G. angulata* (White) is probably a junior synonym of *G. simulatilis* (Schwager) 1883, but the two forms appear to be distinct, although very little is known about the holotype of Schwager.

Globorotalia angulata (White) is distinguished by its very low, trochospirally coiled, umbilico-convex test ; its flat to slightly inflated, imbricate dorsal side, and strongly protruding ventral one ; its angular, truncate, conical chambers, its acute to subacute periphery which has no marginal keel but is covered, in well preserved specimens, with few, stout, spine-like projections which may simulate a keel ; its 4–5 chambers in the last whorl which increase rapidly in size ; its curved, depressed, dorsal sutures and radial, strongly incised, ventral ones ; its granular or rather pitted surface ; its very small, deep, open umbilicus, and its long slit-like aperture which extends to the periphery and is covered by a delicate lip in well preserved specimens.

As mentioned by Bolli (1957*b*) *G. angulata angulata* (White) probably evolved from *G. uncinata uncinata* Bolli in early Middle Paleocene time, although its evolution from the more closely related *G. quadrata* (White) is not excluded. On the other hand it is believed to have evolved in two directions, one leading to *G. angulata abundocamerata* Bolli and the other to *G. aequa* Cushman & Renz.

HYPOTYPE. P.45595.

HORIZON AND LOCALITY. Figured specimen, from sample No. 35, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globorotalia angulata* was first described by White (1928) from the Velasco formation of Mexico, where he recorded it as " a rare form in all horizons from the base of the Velasco up into the lower part of the middle portion of the formation". Apparently, he had confused this species with its ancestor *G. uncinata uncinata* Bolli or with similar forms in the Lower Velasco and thus misinterpreted its range. Contrary to White's observation, Hay (1960) recorded this species throughout the upper part of the Velasco formation with only a rare occurrence in the uppermost part of the Lower Velasco, (from the top of the *G. uncinata* Subzone to the top of the *Globorotalia velascoensis* Zone).

In the Esna–Idfu region, *G. angulata angulata* (White) appears at the basal part of the Middle Paleocene. It is taken as a stratigraphical marker for the Lower–Middle Paleocene boundary (i.e. it separates the Danian from the overlying Middle Paleocene) as it has not been found in the type Danian or in the Danian (of reliable references) elsewhere. Moreover, the first appearance of *G. angulata angulata* coincides with the disappearance of the index species of the Danian rocks below, and with the first appearance of the "*Globigerina*/truncated *Globorotalia* assemblage" which is clearly distinguished from the underlying "*Globigerina*/rounded *Globorotalia* assemblage", characteristic of the Danian in its type section and elsewhere.

The subspecies ranges throughout the Middle and Upper Paleocene of the sections studied. It floods the Middle Paleocene, constituting the main element in planktonic foraminiferal fauna, and characterizes the *Globorotalia angulata* Zone. It continues as an abundant to rare form in the overlying *G. velascoensis* Zone, at the top of which it dies out completely.

All reliable references show clearly that *G. angulata angulata* occurs neither in the Danian nor in the Lower Eocene.

Globorotalia apanthesma Loeblich & Tappan

(Pl. 21, figs. 1*a*–*c*)

1957*a* *Globorotalia apanthesma* Loeblich & Tappan : 187–188, pl. 59, figs. 1*a*–*c* only ; non pl. 48, figs. 1*a*–*c* ; pl. 55, figs. 1*a*–*c* ; pl. 58, figs. 4*a*–*c*.

? 1960 *Globorotalia apanthesma* Loeblich & Tappan, Olsson : 45, pl. 8, figs. 17–19.

Description. Test large, planoconvex, umbilico-convex, coiled in a very low trochospire ; dorsal side almost flat, slightly imbricate ; ventral side strongly protruding ; equatorial periphery subcircular, moderately lobate ; axial periphery subacute with the thick, stout, spine-like projections simulating a marginal keel ; chambers on the dorsal side about 16 in number, increasing gradually in size and arranged in 3 dextrally coiled whorls ; the initial chambers are small, indistinct and almost masked by the surface rugosity ; they are followed by relatively large crescentic chambers ; the last whorl is composed of 6 large, almost flat, slightly imbricate chambers (one of which is broken) ; these are roughly crescentic in the early part, quadrangular to hemispherical later ; on the ventral side the chambers are 6 (5 + 1 broken), large, inflated, angular conical and strongly protruding ; sutures on the dorsal side curved, depressed ; on the ventral side they are radial, strongly incised ; umbilicus very wide, deep and open ; aperture interiomarginal, extraumbilical-umbilical, a broad, arched opening with a narrow delicate lip (only seen in well-preserved specimens) ; wall calcareous, perforate ; surface rough, distinctly nodose, with the nodes tapering out in the form of stout, spine-like projections, especially along the periphery and on the ventral side, and thus simulate a partially-developed pseudo-keel on the periphery of the early chambers.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·43 mm.
Minimum diameter = 0·38 mm.
Thickness = 0·25 mm.

REMARKS. *Globorotalia apanthesma* was first described by Loeblich & Tappan (1957*a*) who stated that it differs from both *G. acuta* Toulmin and *G. angulata* (White). However, one paratype (pl. 48, figs. 1*a–c*) is most probably *G. angulata angulata* (White), a second (pl. 55, figs. 1*a–c*) is possibly *G. angulata abundocamerata* Bolli, while a third (pl. 58, figs. 4*a–c*) shows a clearly developed marginal keel, contrary to the authors' original description and remarks. Similarly, the form described by Olsson (1960) as *G. aspanthesma* appears to be more related to *G. angulata angulata* (White).

Globorotalia apanthesma probably evolved directly from *G. angulata angulata* (White) or indirectly through *G. angulata abundocamerata* Bolli by the development of the heavily spinose surface and wide umbilicus. The morphological features and stratigraphical ranges of the two species substantiate this proposition. On the other hand, *G. apanthesma* is believed to have evolved into *G. hispidicidaris* Loeblich & Tappan, which is morphologically very closely related, and is only found with the latest stages of development of *G. apanthesma*.

HYPOTYPE. P.45596.

HORIZON AND LOCALITY. Figured specimen, from sample No. 40, Gebel Owaina section.

STRATIGRAPHICAL RANGE. Loeblich & Tappan (1957*a*) recorded *G. apanthesma* from the Aquia formation of Maryland and Virginia, the Vincentown formation of New Jersey and the Salt Mountain limestone of Alabama, which they considered to be Upper Landenian (Sparnacian) in age.

It was also recorded by Olsson (1960) from the Hornerstown formation of New Jersey, which he considered as Thanetian–basal Sparnacian.

In the Esna–Idfu region *G. apanthesma* ranges throughout the *G. velascoensis* Zone (Upper Paleocene), being rare to common at its base increasing gradually in number towards its upper part (the *G. aequa*/*G. esnaensis* Subzone), and dying out completely at its top.

Globorotalia berggreni sp. nov.

(Pl. 23, figs. 7*a–c*)

DIAGNOSIS. A *Globorotalia* with roughly triglobular, compressed, umbilico-convex test ; extremely reduced umbilicus ; long, slit-like arched aperture and heavily spinose surface.

DESCRIPTION. Test medium sized, compressed and coiled in a low trochospire ; dorsal side almost flat, but weakly inflated with the chambers slightly compressed towards the periphery ; ventral side strongly inflated ; equatorial periphery roughly triglobular, distinctly lobate and sharply serrate, without a marginal keel ; axial periphery subrounded or rather bluntly angular due to the slight compression of the chambers towards the periphery ; chambers on the dorsal side are not all clear, but appear to be 11 in number, arranged in 2 dextrally coiled whorls ; the initial chambers are small, indistinct, and almost masked by the surface rugosity ; the last whorl is composed of 3½ large subglobular, compressed chambers which increase slowly in size except for the last one which is slightly smaller than the penultimate ; on the ventral side the chambers are 3½, subglobular and strongly inflated ; sutures on the dorsal side short, curved and strongly depressed ; on the ventral side the sutures are radial and strongly incised ; umbilicus reduced to an extremely narrow central pit from which the apertrure starts and the ventral sutures radiate ; aperture interiomarginal extraumbilical-umbilical, a large, crescentic arch extending almost to the periphery ; wall calcareous, perforate ; surface rough, heavily nodose, with the nodes tapering out in the form of stout spine-like projections, especially along the periphery.

DIMENSIONS OF HOLOTYPE.

Maximum diameter	=	0·39 mm.
Minimum diameter	=	0·34 mm.
Thickness	=	0·26 mm.

REMARKS. *Globorotalia berggreni* sp. nov. differs from *G. esnaensis* (Le Roy) in its compressed test, smaller size, fewer chambers in the last whorl, subrounded to subacute axial periphery, much narrower umbilicus and peculiar aperture. The form described by Berggren (1960*a*, pl. 5, figs. 3*a–c*) as *G. esnaensis* (Le Roy) is different from Le Roy's original description and figures, but may probably belong to the present species, although it has more chambers, a more rounded axial periphery and a more umbilical aperture.

Globorotalia berggreni sp. nov. probably evolved from *G. irrorata* Loeblich & Tappan by the development of a more tightly coiled, compressed test, a more spinose surface, a much narrower umbilicus and a long slit-like aperture. On the other hand, it might possibly have evolved from *G. esnaensis* (Le Roy) by the reduction in size of test, its slight compression, and by the development of the very narrow umbilicus and the long, slit-like aperture.

This species is named after Dr. W. A. Berggren of the Geological Institute, University of Stockholm, Sweden.

HOLOTYPE. P.45597.

PARATYPE. P.45598.

HORIZON AND LOCALITY. Holo- and paratype from sample No. 51, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species is a rare form in the upper part of the *G. velascoensis* Zone, the *G. aequa–G. esnaensis* Subzone, of uppermost Paleocene age.

Globorotalia bollii sp. nov.

(Pl. 22, figs. 5*a–d*, 6*a–d*)

1957*b* *Globorotalia rex* Martin ; Bolli : 75, pl. 18, figs. 10–12.

DIAGNOSIS. A *Globorotalia* with medium-sized test ; perfectly flat dorsal side and protruding ventral one ; distinctly well-developed, very broad, heavily beaded keel ; narrow umbilicus and thick, curved, raised, heavily beaded dorsal sutures.

DESCRIPTION. (Holotype, Pl. 22, figs. 5*a–d*). Test medium sized, plano-convex, umbilico-convex, coiled in a very low trochospire ; dorsal side flat ; ventral side strongly protruding ; equatorial periphery roughly quadrate, distinctly lobate with a well-developed, broad, heavily beaded marginal keel ; axial periphery acute ; chambers on the dorsal side about 10, arranged in 2 dextrally coiled whorls ; the initial chambers are small, globular, compressed, almost masked by the surface rugosity, and are followed by typically crescentic chambers which increase gradually in size ; the last whorl is composed of 4½, large, crescentic chambers which increase rapidly in size ; on the ventral side the chambers are 4½, large, angular conical and strongly protruding, with their distal ends meeting closely around the small umbilicus ; sutures on the dorsal side are thickened, raised, curved and heavily beaded ; on the ventral side the sutures are radial and strongly depressed ; umbilicus small, deep and open ; aperture interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface delicately papillose on the dorsal side, more heavily so on the ventral.

DIMENSIONS OF HOLOTYPE.

Maximum diameter	=	0·46 mm.
Minimum diameter	=	0·35 mm.
Thickness	=	0·21 mm.

REMARKS. Bolli (1957*b*) described as *Globorotalia rex* Martin from the upper Lizard Springs formation of Trinidad, a form which differs from the holotype of Martin in its perfectly flat dorsal side ; extremely well-developed, much wider, heavily beaded marginal keel ; thick, raised, beaded dorsal sutures and more tightly coiled chambers. Bolli stated that this form characterizes the *G. rex* Zone at the base of the Eocene.

Globorotalia rex Martin is closely related to *G. aequa* Cushman & Renz, and may be a junior synonym of *G. simulatilis* (Schwager) although very little is known about Schwager's species. On the other hand, the form figured by Bolli (1957*b*) appears to be more closely related to the *G. velascoensis* group, especially to *G. velascoensis parva* Rey. It differs from the latter, only in being smaller, having a rougher surface, a much smaller umbilicus, a less protruding ventral side and a weaker, less ornamented umbilical shoulder.

Careful examination of *G. rex* as described and figured by Martin (1943) from the Lodo formation of California, and by Mallory (1959) from the same formation, showed that the form described by Bolli (1957*b*) as *G. rex* Martin is different and should be considered separately. It is here named *G. bollii* n.sp. after Dr. Hans M. Bolli.

A form with a much rougher surface than the holotype, sub-circular test, and more chambers in the last whorl (Pl. 22, figs. 6a–*d*), may well be a transitional stage between *G. velascoensis velascoensis* and the present species. This substantiates the hypothesis that *G. bollii* evolved from *G. velascoensis velascoensis* in late Paleocene or early Eocene time, as suggested by their morphological features and stratigraphical ranges.

Subbotina (1953, pl. 18, figs. 1*a*–*c*) figured as *G. marginodentata* Subbotina, a form with a flat dorsal side, which may belong to *G. bollii*.

Loeblich & Tappan (1957*a*) described as *G. rex* Martin a form which appears to be different from the holotype of Martin (1943), the hypotype of Mallory (1959), and the present form.

HOLOTYPE. P.45599.

PARATYPE. P.45600.

HORIZON AND LOCALITY. Holo- and paratype, from sample No. 68, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species is common to rare in the *G. wilcoxensis* Zone, which is here considered to represent the basal Eocene ; Bolli's form was also recorded from the Lower Eocene of Trinidad.

Globorotalia compressa (Plummer)

(Pl. 17, figs. 1*a*–3*c*)

1926 *Globigerina compressa* Plummer : 135–136, pl. 8, figs. 11*a*–*c*.
1937*b* *Globigerina compressa* Plummer ; Glaessner : 382, pl. 4, figs. 32*a*–*c*.
1953 *Globigerina compressa* Plummer var. *compressa* Plummer ; Subbotina (pars) : 55, pl. 2, figs. 2*a*–*c* ; non figs. 3*a*–14*c*.
1953 *Globorotalia membranacea* (Ehrenberg) ; Subbotina (pars) : 205, pl. 16, figs. 7*a*–*c*, 10*a*–*c* ; non figs. 8*a*–9*c*, 11*a*–13*c*.
1955 *Globorotalia compressa* (Plummer) Dalbiez & Glintzboeckel (in Cuvillier *et al.*, 1955) : 533, pl. 1, figs. 3*a*–*c*.
1957 *Globigerina compressa* Plummer ; Troelsen : 129, pl. 30, figs. 5*a*–*c*.
1957*a* *Globorotalia compressa* (Plummer) ; Loeblich & Tappan : 188, pl. 40, figs. 5*a*–*c* ; pl. 41, figs. 5*a*–*c* ; pl. 42, figs. 5*a*–*c* ; pl. 44, figs. 9*a*–10*c*.
1960*g* *Globigerina compressa* Plummer ; Hofker : 78–79, text-figs. 35*a*–*c*.
1960*b* *Globorotalia compressa* (Plummer) ; Bolli & Cita : 20–21, pl. 32, figs. 3*a*–*c*.
1962 *Globorotalia* (*Turborotalia*) *compressa* (Plummer) ; Berggren : 94–96, pl. 14, figs. 5*a*–*c*, text-figs. 13 (1–6).

DESCRIPTION. (Specimen, Pl. 17, figs. 2*a*–*c*). Test small, roughly lenticular, slightly elongate, compressed, coiled in a very low trochospire, nearly equally biconvex, or slightly more convex on the ventral side ; equatorial periphery roughly ovoid and distinctly lobate ; axial periphery bluntly acute ; 13 chambers on the dorsal side arranged in 2½ dextrally coiled whorls ; the initial chambers are extremely small, very weakly inflated, globigerine and increase gradually in size ; the last whorl is composed of 5, relatively large, roughly crescentic chambers which are compressed and increase more rapidly in size ; the 5 chambers on the ventral side are roughly lenticular and increase rapidly in size ; sutures on the dorsal side curved, depressed ; on the ventral side they are very slightly curved to nearly straight, radial, depressed ; umbilicus irregular in outline, narrow, shallow and open ; aperture interiomarginal, extraumbilical-umbilical, a narrow, distinct arch with a delicate, flaring lip on top ; wall calcareous, finely perforate ; surface smooth.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter	=	0·25 mm.
Minimum diameter	=	0·16 mm.
Thickness	=	0·10 mm.

MAIN VARIATION.

1. Chambers 12–15, arranged in $2\frac{1}{2}$–3 whorls.
2. Chambers in the last whorl 4–5, rarely 6.
3. Coiling is random with more tendency to dextral coiling (of 95 specimens chosen at random, 28 coiled sinistrally).

REMARKS. Cushman & Todd (1942), Cushman & Bermudez (1949) and Brönnimann (1952) considered this species to belong to *Globorotalia* although their figured forms are not true *G. compressa* (Plummer)

Troelsen (1957), following Brotzen (1948), considerd this species to belong to the genus *Globigerina*. Dalbiez & Glintzboeckel (1955), Bolli (1957*b*), Loeblich & Tappan (1957*a*, *b*), Olsson (1960), Bolli & Cita (1960*a*, *b*), Bermudez (1961), Berggren (1962), and Hillebrandt (1962) removed this species to the genus *Globorotalia*. Berggren (1962), following Banner & Blow's Classification (1959), considered *G.* compressa to belong to the subgenus *Turborotalia*, while Hillebrandt (1962), following Cushman & Bermudez (1949), considered it to belong to the subgenus *Globorotalia*, although the latter's form is not *G. compressa* (Plummer).

Hofker (1960 *g* : 78–79), neglecting Cushman & Bermudez (1949), Bolli, Loeblich & Tappan (1957), and Banner & Blow (1959), considerd this species to belong to the genus *Globigerina* stating that " Fine pores also are found at the somewhat compressed periphery so that there can be no reason to call this species a *Globorotalia*, since the type of that genus has a distinctly poreless and sharp periphery." However, because of the extraumbilical-umbilical position of the aperture, this species is here considered to belong to the genus *Globorotalia*.

Globorotalia compressa (Plummer) is distinguished by its small, compressed, biconvex test ; its strongly curved, depressed sutures on the dorsal side ; its radial, depressed ventral sutures ; and its very smooth surface.

The species is believed to have evolved from *G. pseudobulloides* (Plummer) during the uppermost part of the Middle Danian time. On the other hand, it is believed to have evolved in two directions : one leading to *Globorotalia emilei* sp. nov. and the other to *Globorotalia ehrenbergi* Bolli. *Globorotalia ehrenbergi* is believed to be a transitional stage between *G. compressa* (Plummer) and *G. pseudomenardii* Bolli, although Loeblich & Tappan (1957*a* : 188) considered it synonymous with *G. compressa* (Plummer). Berggren (1962 : 96), stated that " the writer has compared the holotype of *G. ehrenbergi* (U.S.N.M.P. 5060), metatypes and topotypes of *G.*

compressa and labelled specimens of *G. membranacea* from the Lower Foraminiferal beds of the northern Caucasus and has concluded that *G. ehrenbergi* and *G. compressa* are distinct species."

Jennings (1936), Toulmin (1941), Cushman & Todd (1942), Shifflett (1948), Brönnimann (1952*b*), Hamilton (1953) and Reyment (1960) described as *G. compressa,* forms which probably belong to *Globorotalia emilei* sp.nov. Cushman & Bermudez (1949), Subbotina (1953, *pars*), Olsson (1960), and Hillebrandt (1962) described as *G. compressa,* forms which are probably *Globorotalia pseudobulloides* (Plummer).

Subbotina (1953) had confused *G. compressa* (Plummer) with both *G. pseudobulloides* (Plummer) and *G. ehrenbergi* Bolli, while Hofker (1956*c*, 1958*a*) described as *Globigerina compressa* Plummer, forms which are completely different from Plummer's original description and figures (see synonymy).

HYPOTYPES. P.45601–03.

HORIZON AND LOCALITY. Figured specimens, pl. 17, figs. 1*a–c*, from sample No. 31, Gebel Owaina section ; figs. 2*a–c*, from sample No. 30, Gebel Owaina section ; figs. 3*a–c*, from sample No. 7, Gebel El-Kilabiya section.

STRATIGRAPHICAL RANGE. *Globorotalia compressa* (Plummer) was first described from the upper Midway group of Texas (the Wills Point Formation), which, according to Loeblich & Tappan (1957*a*, *b*) is of Upper Danian age.

It was also recorded from the Upper Danian at its type locality in Denmark, and in southern Sweden (Brönnimann 1953 ; Reichel 1953 ; Troelsen 1957 ; Loeblich & Tappan 1957*a*, *b* ; Hofker 1960*g* ; and Berggren 1960*b*, 1962).

All reliable records show that *G. compressa* (Plummer) is a very short ranging species, restricted to the Upper Danian. All records of *G. compressa* from the Maestrichtian (e.g. Meyer 1959 and Hofker 1958*a*, etc.), from the Middle or Upper Paleocene, or from the Lower Eocene (e.g. Jennings 1936 ; Toulmin 1941 ; Cushman & Todd 1942 ; Shifflett 1948 ; Brönnimann 1952*b* ; Hamilton 1953 ; Bolli 1957*b*, and Reyment 1960) are found to be erroneous. Again, the extension of the range of the present species throughout the Danian (e.g. Hay 1960) or throughout the Danian and the Lower Montian (e.g. Bolli & Cita 1960*a*, *b*) is incorrect.

In the Esna–Idfu region, *G. compressa* (Plummer) occurs as a common to abundant form in the Upper Danian and dies out completely before the first appearance of *G. angulata angulata* (White) which marks the Danian–Middle Paleocene boundary.

***Globorotalia* cf. *convexa* Subbotina**

(Pl. 22, figs. 3*a–c*)

? 1953 *Globorotalia convexa* Subbotina : 209, pl. 17, figs. 2*a*–3*c*.

? 1957*a* *Globorotalia convexa* Subbotina ; Loeblich & Tappan : 188–189, pl. 48, figs. 4*a–c* ; pl. 50, figs. 7*a–c* ; pl. 53, figs. 6*a*–8*c* ; pl. 57, figs. 5*a*–6*c* ; pl. 61, figs. 4*a–c* ; pl. 63, figs. 4*a–c*.

DESCRIPTION. Test medium sized, unequally biconvex, coiled in a low trochospire ; dorsal side slightly raised ; ventral side strongly inflated ; equatorial periphery subcircular, moderately lobate ; axial periphery rounded ; chambers on the dorsal side 15, arranged in 2½ sinistrally coiled whorls, increasing gradually in size ; the initial chambers are small, inflated, globigerine and are followed by typically crescentic, overlapping chambers which increase moderately in size ; the last whorl is composed of 5 relatively large, inflated chambers ; on the ventral side the chambers are 5, large, roughly triangular and strongly inflated ; sutures on the dorsal side are strongly curved, depressed in the early part, short, slightly curved and depressed in the later part ; on the ventral side they are almost straight, radial and depressed ; umbilicus narrow, shallow and open ; aperture interiomarginal, extraumbilical-umbilical, a long, narrow arch bordered above by a narrow delicate lip ; wall calcareous, perforate ; surface rough, nodose.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0.37 mm.
Minimum diameter = 0·29 mm.
Thickness = 0·23 mm. (Of last chamber)

REMARKS. *Globorotalia convexa* was first described by Subbotina (1953) who mentioned that it had a wide range of variation and a long stratigraphical range. The form described here differs from the holotype of *G. convexa* in being much larger, in having fewer chambers in the last whorl, a more rounded axial periphery and a more protruding ventral side. It might possibly have evolved into *G. convexa*, as suggested by their stratigraphical distribution.

Globorotalia cf. *convexa* is believed to have evolved from the morphologically similar *G. faragi* sp. nov. by the development of a more tightly coiled test and by an increase in surface rugosity.

Globorotalia convexa of Olsson (1960) is probably *G. nicoli* Martin, that of Berggren (1960*a*) is possibly *G. faragi* sp. nov. and the one of Said & Kerdany (1961) is most probably *G. angulata abundocamerata* Bolli. The form figured by Gartner & Hay (1962) as *G. convexa* has triangular chambers on the dorsal side instead of chambers with the alar or semicircular outline described by Subbotina.

HYPOTYPE. P.45604.

HORIZON AND LOCALITY. Figured specimen, from sample No. 37, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was first described by Subbotina (1953) from the " zone of conical Globorotalias " of the northern Caucasus, which she considered as Lower–Middle Eocene, but is regarded by Berggren (1960*d*) on the basis of its planktonic Foraminifera, to indicate an Upper Paleocene–Lower Eocene age.

Subbotina recorded this species to range from the " Danian? " to the Middle Eocene, occuring in the zones of "*Rotalia*-like Globorotalias ", " flattened Globorotalias ", and " conical Globorotalias " of the northern Caucasus. It was also recorded from the Paleocene– ? Lower Eocene of the Gulf and Atlantic Coastal Plains and from the Velasco formation of Mexico (Loeblich & Tappan 1957*a* ; Hay 1960), and from the Ilerdian " marne bleue " of Mont Cayla, France (Gartner & Hay 1962).

In the Esna–Idfu region *G.* cf. *conexa* appears in the basal part of the *G. velascoensis* Zone (Upper Paleocene) : it continues as a rare form throughout this zone, and dies out completely at its top.

Globorotalia ehrenbergi Bolli

(Pl. 17, figs. 5*a–c*)

1957*b* *Globorotalia ehrenbergi* Bolli : 77, pl. 20, figs. 18–20.
1960*b* *Globorotalia ehrenbergi* Bolli ; Bolli & Cita : 21–22, pl. 33, figs. 4*a–c*.

DESCRIPTION. Test small, roughly lenticular, compressed, coiled in a very low trochospire ; dorsal side very gently convex ; ventral side very slightly inflated ; equatorial periphery roughly circular, strongly lobate ; axial periphery acute, with a faintly developed keel on the last chamber (partially damaged on the figured specimen) ; about 15 chambers on the dorsal side, increasing slowly in size at first but more rapidly later, arranged in 2½–3 whorls ; the initial chambers are exceedingly small, indistinct, globigerine and slightly inflated ; the chambers of the second whorl are relatively larger, globular to roughly crescentic, and compressed ; the last whorl is composed of 5, relatively large, roughly lenticular, compressed chambers, which increase moderately in size ; the 5 chambers on the ventral side are roughly triangular and slightly inflated ; sutures on the dorsal side are slightly curved, distinctly depressed ; on the ventral side they are almost straight, radial and strongly incised ; umbilicus small, shallow and open ; aperture interiomarginal, extraumbilical-umbilical, a narrow long arch, covered by a delicate lip ; wall calcareous, perforate ; surface smooth.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·25 mm.
Minimum diameter = 0·20 mm.
Thickness = 0·10 mm.

REMARKS. *Globorotalia ehrenbergi* is distinguished by its small, lenticular, compressed, smooth test ; its curved, depressed dorsal sutures, and radial, incised ventral ones ; its acute axial periphery and weakly developed partial keel ; its small shallow umbilicus ; and its narrow, long aperture with its delicate apertural lip.

This species was previously included by various authors within *Globorotalia membranacea* (Ehrenberg), a recognized *nomen nudum*, under which several morphologically and stratigraphically distinct forms had been described. In addition to the known Paleocene species such as *G. compressa* (Plummer), *G. ehrenbergi* Bolli, *G. emilei* sp. nov., *G. pseudomenardii* Bolli, various other forms from stratigraphically distinct horizons were considered as *G. membranacea* (Ehrenberg). Subbotina (1953), for example, included under *G. membranacea* (Ehrenberg), forms which are actually *G. compressa*, *G. ehrenbergi* and *G. pseudomenardii*.

G. ehrenbergi probably evolved from *G. compressa*, and is considered as an intermediate stage between it and *G. pseudomenardii*. This is substantiated by their morphological characters and stratigraphical ranges, although it is not excluded that *G. ehrenbergi* has possibly evolved from *G. imitata* Subbotina ; extremely compressed forms of *G. imitata* closely resemble *G. ehrenbergi* and may be transitional to it.

Again, as previously mentioned above (pp. 204, 205), Loeblich & Tappan (1957*a* : 188) included *G. ehrenbergi* in their synonymy of *G. compressa*, but the stratigraphical ranges and morphological characterisitcs of the two species substantiate their separate identity.

HYPOTYPE. P.45605.

HORIZON AND LOCALITY. Figured specimen, from sample No. 37, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was described by Bolli (1957*b*) from the Paleocene, lower Lizard Springs formation of Trinidad, where it was found to range throughout the *G. pusilla pusilla* Zone and the lower part of the *G. pseudomenardii* Zone, here considered as upper Middle Paleocene–lower Upper Paleocene respectively.

It was recorded from almost the same horizon in the Paderno d'Adda section of northern Italy (Bolli & Cita 1960*a*, *b*), from the Paleocene Madruga formation of Cuba (Cushman & Bermudez 1949) as *G. membranacea* (Ehrenberg), the Paleocene of the Caucasus region (Subbotina 1953), the Lower Paleocene of Nekhl section, northern Sinai, Egypt (Said & Kenawy 1956), and from the Danian–Landenian of Austria (Hillebrandt 1962) : this last author apparently confused *G. ehrenbergi* with various other forms as can be seen from his figures.

In the Esna–Idfu region *G. ehrenbergi* appears in the Upper Danian and continues as a rare to common form to the basal part of the Upper Paleocene *G. pseudomenardii* Subzone.

Globorotalia emilei sp. nov.

(Pl. 17, figs. 9*a–c*)

? 1936 *Globigerina compressa* Plummer ; Jennings : 193, pl. 4 (31), fig. 8.
? 1941 *Globigerina compressa* Plummer ; Toulmin : 607, pl. 82, figs. 1, 2.
? 1942 *Globigerina compressa* Plummer ; Cushman & Todd (pars) : 44, pl. 8, fig. 6 ; non fig. 5.
? 1952*b* *Globigerina compressa* Plummer ; Brönnimann : 25, pl. 2 (12), figs. 19–24.
1953 *Globorotalia membranacea* (Ehrenberg) ; Le Roy : 32, pl. 3, figs. 13–14.
1953 *Globigerina compressa* Plummer ; Hamilton : 221, pl. 31, figs. 14, 15.
1957*b* *Globorotalia elongata* Glaessner ; Bolli : 77–78, pl. 20, figs. 11–13.
1957*a* *Globorotalia elongata* Glaessner ; Loeblich & Tappan (pars) : 189, pl. 45, figs. 5*a–c* ; pl. 46, figs. 5*a–c* ; ? pl. 49, figs. 7*a–c* ; pl. 54, figs. 1*a*–4*c* ; pl. 59, figs. 4*a–c* ; pl. 60, figs. 9*a–c* ; non pl. 48, figs. 5*a–c* ; pl. 54, figs. 5*a–c* ; pl. 63, figs. 2*a–c*.
1960 *Globorotalia elongata* Glaessner ; Olsson : 45–46, pl. 9, figs. 4–6.

DIAGNOSIS. A *Globorotalia* with elongate, very low trochospiral, slightly compressed test ; subrounded to subacute axial periphery ; crescentic, rapidly enlarging chambers in last whorl ; curved, depressed, dorsal sutures and nearly radial, incised ventral ones ; smooth surface and wide, open umbilicus.

DESCRIPTION. Test medium sized, unequally biconvex, compressed, coiled in a very low trochospire ; dorsal side almost flat although the chambers, especially the last one, are slightly inflated ; ventral side moderately inflated ; equatorial periphery roughly ovoid, elongate and moderately lobate ; axial periphery bluntly acute, with a faintly developed pseudo-keel on the last chamber ; chambers on the dorsal side nearly 13, arranged in two dextrally coiled whorls ; the initial chambers are very small, indistinct and are followed by crescentic, overlapping chambers ; the last whorl is composed of 6, large, slightly inflated, compressed chambers which increase so rapidly in size that the last chamber constitutes about $\frac{1}{3}$ of the test ; the 6 chambers on the ventral side increase rapidly in size and are inflated, triangular to sub-globular ; sutures on the dorsal side curved, strongly depressed ; on the ventral side they are nearly radial and distinctly depressed ; umbilicus elongate in outline, fairly wide and open ; aperture a low, narrow arch, interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface delicately papillose in the early part, becoming smoother towards the last chamber.

DIMENSIONS OF HOLOTYPE.

Maximum diameter = 0·34 mm.
Minimum diameter = 0·22 mm.
Thickness = 0·14 mm.

MAIN VARIATION.

1. Chambers in the last whorl 4–6.
2. Coiling is fairly random but with a tendency to be dextral ; (of 47 specimens studied, 28 coiled dextrally).
3. The axial periphery is either rounded or pinched out to form a thin pseudo-keel.

REMARKS. *Globorotalia emilei* sp. nov. is morphologically similar to *G. compressa* (Plummer), *G. inflata* Hussey, *G. planoconica* Subbotina, *G. pseudomenardii* Bolli and *G. pseudoscitula* var. *elongata* Glaessner. It is distinguished from *G. compressa* by its larger, less compressed test, radially elongate last chamber and partially developed marginal keel. *Globorotalia inflata* Hussey which was described from the Eocene, Claiborne, Cane River formation of Louisiana, is morphologically very similar, although it was very briefly described. However, apart from the difference in stratigraphical range it appears to be more planoconvex, strongly umbilico-convex, with a much deeper umbilicus and a well-developed apertural lip, and to lack the partially developed marginal keel. *Globorotalia planoconica* Subbotina is much smaller, with a planoconvex more tightly coiled test, a much narrower umbilicus, less radially elongate last chamber, an occasional entire keel and an apertural lip. *G. pseudomenardii* Bolli is distinguished by its chambers which increase more rapidly in size, its well-developed marginal keel and sharply acute axial periphery. *G. pseudoscitula* var. *elongata* Glaessner is much smaller, has a raised dorsal spire with a much flattened last chamber, more tightly coiled test, less lobate periphery and more curved ventral sutures. It was described from the so-called Lower Eocene of northwestern Caucasus, while the present species was only recorded from the Middle and lower Upper Paleocene. Glaessner's variety needs more detailed description and its stratigraphical range needs to be more precisely defined to prove its relationship to the present species, which may represent the ancestral stock from which it has directly or indirectly evolved, and with which it has been often confused. Bolli (1957*b*) raised this variety to specific rank, changing its name to *G. elongata* Glaessner. However, the forms figured by him are different from the holotype of Glaessner, but most probably belong to the present species. He was followed by Loeblich & Tappan (1957*a*), Olsson (1960) and Hillebrandt (1962). Loeblich & Tappan included in *G. elongata* forms which are identical with the present species, and others which lack the radially elongated last chamber, characteristic of the species (see synonymy). These forms, as can be seen from their figures, should be considered separately. The form figured by Olsson (1960) as *G. elongata* Glaessner conforms well with the present species, while that described by Hillebrandt is different from both the holotype of Glaessner and the present form.

Globorotalia emilei sp. nov. was confused with *G. membranacea* (Ehrenberg) and with *G. compressa* (Plummer) as seen in synonymy. *Globorotalia membranacea*, although much confused, is a Pliocene form, while *G. compressa* is only known from the Danian.

Globorotalia emilei sp. nov. is believed to have evolved from *G. compressa* (Plummer) by the increase in the size of test and the development of the strongly elongated chambers in the last whorl, and the partially developed keel. On the other hand, it is believed to have evolved in two directions : one leading to *G. pseudomenardii* Bolli, by the development of the marginal keel and the sharply acute axial periphery, and the other to *G. troelseni* Loeblich & Tappan, by the development of the tendency towards a somewhat evolute coiling in the last whorl. The present species is named after Professor Emile A. Pessagno, Jr., of the University of California, Davis, California.

HOLOTYPE. P.45606.

PARATYPES. P.45668.

HORIZON AND LOCALITY. Holo- and paratypes, from sample No. 33, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globorotalia emilei* sp. nov. ranges throughout the Middle and most of the Upper Paleocene of the Esna–Idfu region. It appears at the base of the *G. angulata* Zone, and continues as a common to abundant form to the basal part of the *G. aequa*/*G. esnaensis* Subzone. Bolli (1957*b*) recorded his *G. elongata* Glaessner, which most probably belongs to *G. emilei*, from the Paleocene, lower Lizard Springs formation of Trinidad, where it was shown to range through the *G. pseudomenardii*–*G. velascoensis* Zones. It was also recorded as *G. elongata* Glaessner, from the Paleocene of the Gulf and Atlantic Coastal plains and of Mexico (Loeblich & Tappan 1957*a* ; Olsson 1960), as *G. membranacea* (Ehrenberg) from the Paleocene of the Maqfi section, Farafra Oasis, Egypt (Le Roy 1953), and as *G. compressa* (Plummer) from the Paleocene of various parts of the world (see synonymy).

Globorotalia esnaensis (Le Roy)

(Pl. 21, figs. 6*a*–*c*)

1953 *Globigerina esnaensis* Le Roy : 31, pl. 6, figs. 8–10.

1953 *Acarinina pseudotopilensis* Subbotina (pars) : 227, pl. 21, figs. 8*a*–9*c* ; pl. 22, figs. 2*a*–3*c*, non pl. 22, figs. 1*a*–*c*.
? 1953 *Globigerina varianta* Subbotina (pars) : 63, pl. 3, figs. 8*a*–*c* only ; non pl. 3, figs. 5*a*–7*c*, 10*a*–12*c* ; pl. 4, figs. 1*a*–3*c* ; pl. 5, figs. 1*a*–3*c*.
1959 *Globigerina esnaensis* Le Roy ; Nakkady : 461, pl. 3, figs. 2*a*–*c*.
1960 *Globorotalia pseudotopilensis* (Subbotina) Said : 283, pl. 1, figs. 3*a*–*c*.
? 1960*a* *Globorotalia wilcoxensis* Cushman & Ponton ; Berggren : 97, pl. 13, figs. 3*a*–4*c*.
1961 *Globorotalia esnaensis* (Le Roy) Said & Kerdany : 328, pl. 1, figs. 6*a*–*c*.
1962 *Globorotalia esnaensis* (Le Roy) ; Gartner & Hay : 563–564, pl. 2, figs. 4*a*–*c*.

DESCRIPTION. Test large, globigerine, umbilico-convex, coiled in a very low trochospire ; dorsal side slightly flattened especially in the early part ; ventral side highly convex and strongly inflated ; equatorial periphery roughly quadrate, distinctly lobate and coarsely spinose ; axial periphery broadly rounded ; chambers on the dorsal side about 9, arranged in 2 dextrally coiled whorls; the initial chambers are small, inflated, globigerine, and are masked by the surface rugosity ; the last whorl is composed of 4 large chambers which increase so rapidly in size that the last, which is very strongly inflated, constitutes about $\frac{1}{3}$ of the test ; the first 3 chambers in this whorl are roughly rectangular and arcuate, while the last is subglobular on the dorsal side ; on the ventral side the chambers are 4, large, subglobular, and strongly inflated ; sutures on dorsal side straight, radial and depressed ; on ventral side they are straight, radial, and strongly incised ; umbilicus medium-sized, shallow and open ; aperture an elongate, low arch, interiomarginal, extraumbilical-umbilical ; wall calcareous, finely perforate ; surface rough, nodose or rather coarsely spinose especially on the dorsal side and along the periphery.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·50 mm.
Minimum diameter = 0·40 mm.
Thickness = 0·28 mm.

MAIN VARIATION.

1. Chambers 8–10, most commonly 9, arranged in 2–2½ whorls which are generally dextrally coiled, but sinistral forms also occur ; (of 470 specimens studied, 180 coiled sinistrally).
2. The last whorl is composed of 4–5 chambers, but 4 is most common.

REMARKS. *Globorotalia esnaensis* was first described by Le Roy, (February 1953) as *Globigerina esnaensis* n.sp. from the Esna shales of the Maqfi section, Farafra Oasis, Egypt. Subbotina (November 1953) described as *Acarinina pseudotopilensis* n.sp. a form which conforms well with Le Roy's original description and figures of *G. esnaensis*, and is thus considered a junior synonym. In the same work, Subbotina figured and described as *Globigerina varianta* n.sp., a form which probably belongs to *G. esnaensis* (see synonymy).

Loeblich & Tappan (1957*a*) removed this species to the genus *Globorotalia*, because of the extraumbilical-umbilical position of its aperture, but their figures are different from the holotype of *G. esnaensis*.

The forms described as *Globorotalia pseudotopilensis* (Subbotina) by Loeblich & Tappan (1957*a*), Berggren (1960*a*) and Reyment (1960) are different from *G. esnaensis* and from the holotype *G. pseudotopilensis*, while that of Said (1960) probably belongs to *G. esnaensis*.

Berggren (1960*a*) and Bermudez (1961) described as *Globororalia esnaensis* (Le Roy) and *Globigerina esnaensis* Le Roy, respectively forms which are different from the holotype of Le Roy. However, the former author (pl. 13, figs 3*a*–4*c*) described as *Globorotalia wilcoxensis* Cushman & Ponton, forms which probably belong to *G. esnaensis*. Berggren (1960*b* : 50–51) wrongly considered *G. esnaensis* figured by Nakkady (1959) as *G. soldadoensis* Brönnimann, while Hillebrandt (1962 : 142–143) included *G. esnaensis* in the synonymy of a form described as *Globorotalia* (*Acarinina*) *soldadoensis* (Brönnimann).

Globorotalia esnaensis (Le Roy) is distinguished by its large test ; small number of chambers ; slightly flattened dorsal side and strongly protruding ventral one ; its quadrate, lobate, equatorial periphery and rounded axial periphery ; its radial, depressed sutures on both sides and rough nodose surface.

The species probably evolved from *G. tribulosa* Loeblich & Tappan by the increase in the size of test and in the surface rugosity, and by the development of a more tightly coiled test, less lobate periphery, and a much narrower aperture. On the other hand, *G. esnaensis* is believed to have evolved into *G. wilcoxensis* Cushman & Ponton through *G. whitei* Weiss, by further flattening of the dorsal side, the development of a sub-acute axial periphery in the later part of the test, and by the reduction in the surface rugosity on the last chambers. Similarly, it has also probably involved into *G. berggreni* sp. nov. as mentioned above (p. 201).

HYPOTYPE. P.45607.

HORIZON AND LOCALITY. Figured specimen from sample No. 49, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was first described from the basal part of the Esna shale (Unit II of Le Roy) of the Maqfi section, Farafra Oasis, Egypt ; it was found to be abundant throughout this unit, becoming scarce higher in the section. Le Roy tentatively considered this unit to be Lower Eocene in age while Said & Kerdani (1961) considered it to be Landenian.

Nakkady (1959) recorded *Globigerina esnaensis* Le Roy throughout the Maestrichtian–Paleocene of the Um-El-Ghanayem section, Kharga Oasis, Egypt. Evidently he confused this important species with superficially similar *Rugoglobigerina* and *Globorotalia* species, thus completely obscuring its true range.

G. esnaensis was also recorded from the Lower Tertiary of the northern Caucasus (Subbotina 1953), the Paleocene of northern Sinai, Egypt (Said & Kenawy 1956), the Upper Landenian–Lower Eocene of the Gulf and Atlantic Coastal Plains (Loeblich & Tappan 1957*a*, *b*), the Lower Eocene of Denmark (Berggren 1960*a*), the ? Landenian Esna shales of Luxor section, Egypt (Said 1960), the Landenian Esna shales of the Farafra Oasis, Egypt (Said & Kerdany 1961), and from the type Ilerdian of Spain and the Ilerdian of Mont Cayla, France (Gartner & Hay 1962).

In the Esna–Idfu region *G. esnaensis* (Le Roy) appears in the middle of the *G. velascoensis* Zone. It floods the upper part of this zone characterizing, together with

G. aequa, the *G. aequa/G. esnaensis* Subzone. It crosses the Paleocene/Lower Eocene boundary and fades out gradually in the basal Eocene. All records of *G. esnaenensis* from rocks older than the upper part of the Upper Paleocene are erroneous.

Globorotalia faragi sp. nov.

(Pl. 19, figs. 4*a–c*)

Diagnosis. A *Globorotalia* with biconvex, low trochospirally coiled test ; depressed sutures ; very narrow umbilicus ; long slit-like aperture and papillose surface.

Description. Test medium sized, trochospirally coiled, inflated ; dorsal side slightly convex with the early whorls moderately raised above the level of the final whorl ; ventral side strongly inflated ; equatorial periphery almost circular, strongly lobate ; axial periphery rounded ; chambers on the dorsal side 16, arranged in 3 dextrally coiled whorls ; the initial ones are small, inflated, globigerine and are followed by slightly larger, ovoid chambers ; the last whorl is composed of 5 large, subglobular chambers which are slightly elongated in the direction of coiling and increase slowly in size ; on the ventral side the chambers are 5, large, subglobular, inflated and increase so slowly that they all appear to be roughly equal in size ; sutures on the dorsal side curved, depressed in the early part, almost straight and depressed later ; on the ventral side the sutures are straight, radial and strongly incised ; umbilicus very small ; aperture a long narrow slit, interiomarginal, extraumbilical-umbilical, extending slightly on to the dorsal side ; wall calcareous, perforate ; surface delicately papillose on the dorsal side, more strongly so on the ventral.

Dimensions of holotype.

Maximum diameter = 0·43 mm.
Minimum diameter = 0·35 mm.
Thickness = 0·26 mm.

Main variation.

1. Test small to medium sized, moderately to strongly inflated.
2. Coiling is mainly dextral (of 42 specimens studied, 4 coiled sinistrally).
3. The aperture is interiomarginal, extraumbilical-umbilical, but in some specimens it extends slightly on to the dorsal side.
4. The surface is delicately to strongly papillose.

Remarks. *Globorotalia faragi* is morphologically similar to *G. reissi* Loeblich & Tappan from which it is distinguished by its much larger size, papillose surface and rounded axial periphery. It differs from *G. convexa* Subbotina in its globular form, larger size, non-spinose surface, rounded axial periphery and raised early whorls on the dorsal side.

The form described here as *Globorotalia* cf. *convexa* is morphologically very similar to the present species, but is distinguished by its flat, less globular, strongly overlapping chambers which increase more rapidly in size, are typically crescentic in the early stage and roughly quadrangular later.

Globorotalia faragi possibly evolved from *Globigerina arabica* sp. nov. by a reduction in the size of test, number of chambers, height of the dorsal spire, and by the development of the extraumbilical-umbilical aperture. On the other hand, *G. faragi* is believed to have evolved into *G.* cf. *convexa* by a loss of globularity of the test, and by the development of flat, crescentic, tightly coiled, strongly overlapping chambers which become roughly quadrangular in the later part. The stratigraphical ranges of these species support this hypothesis.

This species is named after Professor I. A. M. Farag, Cairo University.

HOLOTYPE. P.45608.

PARATYPES. P.45609.

HORIZON AND LOCALITY. Holo- and paratypes from sample No. 34, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species ranges from the uppermost Danian to the uppermost Paleocene, being common in the Middle Paleocene and rare in the Upper Paleocene.

Globorotalia hispidicidaris Loeblich & Tappan
(Pl. 21, figs. 5*a–c*)

1957*a* *Globorotalia hispidicidaris* Loeblich & Tappan : 190, pl. 158, figs. 1*a–c*.

DESCRIPTION. Test large, umbilico-convex, coiled in a low trochospire ; dorsal side gently convex ; ventral side strongly protruding ; equatorial periphery circular, moderately lobate and heavily spinose ; axial periphery angular ; the concentrated nodes and spines along the periphery simulate a marginal pseudo-keel, although the species is typically non-keeled ; chambers on the dorsal side 17 in number, increasing slowly in size and arranged in 3 dextrally coiled whorls ; each whorl is lightly raised relative to the one following ; the initial chambers are small, inflated, globigerine, almost masked by the surface rugosity, and are followed by large, crescentic, slightly inflated chambers ; the last whorl is composed of 6 large, roughly crescentic to quadrangular chambers which increase slowly in size except for the last, which is slightly smaller than the penultimate ; on the ventral side the chambers are 6, large, high, conical, almost equal in size and meet in a relatively high umbilical shoulder ; sutures on the dorsal side curved, depressed ; on the ventral side they are radial, strongly incised ; umbilicus wide, deep and open ; aperture interiomarginal, extraumbilical-umbilical, a long, narrow slit extending to the periphery ; wall calcareous, perforate ; surface rough, distinctly nodose and heavily spinose, with the nodes and spines concentrated along the periphery simulating a thick, spinose, pseudo-keel.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·44 mm.
Minimum diameter = 0·37 mm.
Thickness = 0·29 mm.

REMARKS. *Globorotalia hispidicidaris* is distinguished by its large, heavily spinose test ; its numerous chambers which increase slowly in size ; its gently convex dorsal side and strongly protruding ventral side ; its high umbilical shoulder ; wide, deep umbilicus; its curved, depressed dorsal, and radial strongly incised ventral sutures ; its subcircular, lobate, densely spinose, equatorial periphery and angular axial one ; and its slit-like, long, narrow aperture.

Globorotalia hispidicidaris possibly evolved from *G. apanthesma* Loeblich & Tappan, by the development of the unequally biconvex test, angular axial periphery, more densely spinose surface, a high umbilical shoulder, a narrower, deeper umbilicus, a narrower, longer aperture, and a thick spinose pseudo-keel. On the other hand, it is not excluded that *G. hispidicidaris* has evolved from *G. mckannai*, with forms like *G. strabocella* Loeblich & Tappan as transitional stages.

HYPOTYPE. P.45610.

HORIZON AND LOCALITY. Figured specimen, from sample No. 55, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was first described by Loeblich & Tappan (1957*a*) from the Aquia formation of Virginia which they considered to be of Upper Landenian or Sparnacian age.

In the Esna–Idfu region, *G. hispidicidaris* is a rare to common form in the uppermost part of the *G. velascoensis* Zone (the upper part of the *G. aequa–G. esnaensis* Subzone) of uppermost Palecoene age.

Globorotalia imitata Subbotina
(Pl. 17, figs. 6*a–c*)

1953 *Globorotalia imitata* Subbotina : 206–207, pl. 16, figs. 14*a*–16*c*.

1957*a* *Globorotalia imitata* Subbotina ; Loeblich & Tappan (*pars*) : 190–191, pl. 45, figs. 6*a–c* ; pl. 54, figs. 8*a–c*, ? 9*a–c* ; pl. 59, figs. 5*a–c* ; pl. 63, figs. 3*a–c* ; ? pl. 44, figs. 3*a–c*.

1960 *Globorotalia imitata* Subbotina ; Olsson : 46, pl. 9, figs. 7–9.

DESCRIPTION. Test small, coiled in a very low trochospire ; dorsal side flat in the early part, weakly inflated later ; ventral side moderately inflated, slightly protruding equatorial periphery subcircular, lobate ; axial periphery rounded ; chambers on the dorsal side 14, arranged in 2 sinistrally coiled whorls ; the initial chambers are small, globigerine, compressed and very tightly coiled ; the last whorl is composed of 6 relatively large, roughly globular and weakly inflated chambers, which increase moderately in size except for the last which is slightly smaller than the penultimate ; on the ventral side the chambers are 6, globular and moderately inflated ; sutures on the dorsal side curved, depressed in the early part, almost straight, radial and depressed later ; on the ventral side they are straight, radial and strongly depressed ; umbilicus relatively large, shallow and open ; aperture interiomarginal, extraumbilical-umbilical, a low arch bordered above by a narrow, delicate lip ; wall calcareous, perforate ; surface smooth.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·25 mm.
Minimum diameter = 0·20 mm.
Thickness = 0·11 mm. (of last chamber)

REMARKS. Specimens of *G. imitata* Subbotina from the Esna–Idfu region conform well with the original description and figures, although the specimen figured here is slightly larger, has subglobular rather than oval chambers, and has more chambers in the final whorl. However, as mentioned by Subbotina, such minor differences fall well within the range of variation of the species.

G. imitata was described by Subbotina as having a close resemblance both to *G. membranacea* and *G. compressa* (Plummer). However, Subbotina's *G. membranacea* included representatives of *G. compressa*, *G. ehrenbergi* and *G. pseudomenardii*, all of which are morphologically and stratigraphically distinct from *G. imitata*. The latter species is believed to have evolved from *G. pseudobulloides* (Plummer) by reduction in the size of test and rate of chamber growth, by flattening of the dorsal side and the development of a smooth test. However, it might have evolved from *G. compressa* although no direct evidence was found. *G. imitata* probably evolved into *G. ehrenbergi* Bolli, by the development of a slightly more compressed test and a weak keel on the last chamber. Forms of *G. ehrenbergi* without the partially developed keel are believed to be transitional to *G. imitata*.

Said (1960) and Said & Kerdany (1961) described as *G. imitata* Subbotina (from the Lower Eocene Thebes limestones of Luxor and the Upper Paleocene Esna shales of Farafra Oasis respectively) forms which are completely different from Subbotina's original description and figures. Said's form was recorded as ranging through the Lower Eocene only, whereas *G. imitata* was first described from the Danian and was found to die out completely long before the Lower Eocene. Said relied on Loeblich & Tappan's record of *G imitata* from the Nanafalia formation of Alabama which they considered as Lower Eocene, but both Bramlette & Sullivan (1961) and Gartner & Hay (1962) assigned this formation to the Paleocene.

HYPOTYPE. P.45611.

HORIZON AND LOCALITY. Figured specimen, from sample No. 7, Gebel El-Kilabiya section.

STRATIGRAPHICAL RANGE. The species was first described by Subbotina (1953) from the zone of " *Rotalia*-like *Globorotalia* ", Elburgan horizon, Northern Caucasus, which she tentatively assigned to the Danian. It was also recorded from the Danian of the Gulf and Atlantic Coastal Plains of the U.S.A., where it was found to continue through the overlying Landenian and the so-called Lower Eocene (Loeblich & Tappan 1957*a* ; Olsson 1960).

In the Esna–Idfu region *G. imitata* occurs as a rare to common form in the Upper Danian (the Lower and Middle Danian being missing), and continues as a rare form up to the basal part of the Upper Paleocene *G. velascoensis* Zone.

Globorotalia irrorata Loeblich & Tappan

(Pl. 23, figs. 9*a*–*c*)

1957*a* *Globorotalia irrorata* Loeblich & Tappan : 191, pl. 46, figs. 2*a*–*c* ; pl. 61, figs. 5*a*–*c*.

DESCRIPTION. Test medium sized, coiled in a low trochospire ; dorsal side almost flat, weakly inflated ; ventral side strongly inflated ; equatorial periphery roughly quadrate, moderately lobate ; axial periphery subrounded ; chambers on the dorsal side about 13, arranged in $2\frac{1}{2}$ dextrally coiled whorls ; the initial chambers are very small, indistinct and almost masked by the surface rugosity; they are followed by much large, roughly globular, compressed chambers which increase slowly in size ; the last whorl is composed of 4 large, roughly ovoid, slightly inflated chambers which are elongated in the direction of coiling, and increase slowly in size, except for the last which is much smaller than the penultimate ; on the ventral side the chambers are 4, large, globular and strongly inflated ; sutures on the dorsal side slightly curved, depressed ; on the ventral side they are straight, radial and strongly incised ; umbilicus small, deep and open ; aperture a low, interiomarginal, extraumbilical-umbilical slit ; wall calcareous, perforate ; surface heavily nodose with the nodes tapering out in the form of thick, stout, spine-like projections especially on the ventral side and along the periphery.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·43 mm.
Minimum diameter = 0·33 mm.
Thickness = 0·28 mm.

REMARKS. Berggren (1960*a*) removed this species to the genus *Globigerina*, but the forms figured by him are different from the type specimens of Loeblich & Tappan (1957*a*).

Globorotalia irrorata is distinguished from *Globigerina soldadoensis* Brönnimann by its larger size, more globular chambers, more rounded and lobate periphery, and extraumbilical aperture. It differs from *Acarinina intermedia* Subbotina in its quadrate outline, chambers which increase slowly in size, and much smaller last chamber. *Acarinina clara* Khalilov (1956) is closely related to the present species, but has a higher dorsal side, a greater number of chambers, more whorls and a densely porous surface with short spines between the pores.

Globorotalia irrorata probably evolved from *G. quadrata* (White) by the development of the heavily spinose surface, and into *G. berggreni* sp. nov. by the increase in the rate of coiling and in the surface rugosity, by the slight compression of test, the reduction in the size of the umbilicus, and by the development of the long narrow aperture. The stratigraphical distribution of these species substantiate this proposition although no direct evidence was recorded.

HYPOTYPE. P.45612.

HORIZON AND LOCALITY. Figured specimen, from sample No. 51, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was described by Loeblich & Tappan (1957*a*) from the Coal Bluff marl member of the Naheola formation, and from the Nanafalia formation of Alabama which they considered as Upper Thanetian and Lower Eocene respectively, although the latter is most probably of Upper Paleocene age as well.

In the Esna–Idfu region *G. irrorata* is a rare to common form in the *G. aequa*/*G. esnaensis* Subzone of uppermost Paleocene age.

Globorotalia kilabiyaensis sp. nov.

(Pl. 17, figs. 4*a–c*)

DIAGNOSIS. A *Globorotalia* with concavo-convex, compressed test ; lenticular, chambers which increase rapidly in size ; radial, depressed sutures ; wide umbilicus and almost perfectly smooth surface.

DESCRIPTION. Test medium-sized, concavo-convex, strongly compressed, coiled in a very low trochospire ; dorsal side slightly convex, ventral side concave ; equatorial periphery roughly ovoid, slightly elongate, moderately lobate ; axial periphery subrounded, compressed ; chambers on the dorsal side 13, arranged in 2 sinistrally coiled whorls ; the initial ones are small, globigerine, compressed and increase slowly in size ; the last whorl is composed of 4½, roughly lenticular, slightly compressed chambers which increase rapidly in size ; on the ventral side the chambers are 4½, roughly lenticular and increase rapidly in size ; sutures on the dorsal side curved, depressed in the early part, almost straight, depressed later ; on the ventral side they are straight, radial and strongly depressed ; umbilicus large, shallow and open ; aperture interiomarginal, extraumbilical-umbilical, covered with a prominent, flaring lip ; wall calcareous, perforate ; surface perfectly smooth with few, small, delicate papillae on the ventral side of the early chambers.

DIMENSIONS OF HOLOTYPE.

Maximum diameter = 0·300 mm.
Minimum diameter = 0·225 mm.
Thickness = 0·100 mm.

REMARKS. *Globorotalia kilabiyaensis* sp. nov. is distinguished from *G. compressa* (Plummer) by its distinctly concavo-convex test, much wider umbilicus and delicately papillose surface. The form described as *G. compressa* by Loeblich & Tappan (1957*a*, pl. 44, figs. 9*a–c*) shows a slightly concave ventral side and may be transitional between *G. compressa* and *G. kilabiyaensis*.

HOLOTYPE. P.45613.

PARATYPE. P.45614.

HORIZON AND LOCALITY. Holo- and paratypes, from sample No. 7, Gebel El-Kilabiya section.

STRATIGRAPHICAL RANGE. *Globorotalia kilabiyaensis* sp. nov. occurs in abundance in the Upper Danian rocks of the Esna-Idfu region, immediately above the disconformity separating it from the underlying Maestrichtian strata. It ranges throughout the Upper Danian, fading out gradually towards its top, and dying out completely before the first appearance of *G. angulata angulata*, which marks the base of the Middle Paleocene.

Globorotalia loeblichi sp. nov.

(Pl. 23, figs. 1*a–c*)

? 1953 *Acarinina pseudotopilensis* Subbotina (pars) : 227, pl. 22, figs. 1*a–c* ; non figs. 2*a*–3*c*, pl. 21, figs. 8*a*–9*c*.

? 1957*a* *Globorotalia aequa* Cushman & Renz ; Loeblich & Tappan (pars) : 186, pl. 59, figs. 6*a–c* ; pl. 64, figs. 4*a–c* ; ? pl. 60, figs. 3*a–c* ; non pl. 46, figs. 7*a*–8*c*, pl. 50, figs. 6*a–c*, pl. 55, figs. 8*a–c* (?).
? 1961 *Globorotalia triplex* (Subbotina) ; Said & Kerdany : 330, pl. 1, figs. 11*a–c*.
? 1962 *Globorotalia* (*Truncorotalia*) *aequa simulatilis* (Schwager) ; Hillebrandt : 134–135, pl. 13, figs. 6*a*–8*c*.
? 1962 *Globorotalia* (*Acarinina*) *quetra* Bolli ; Hillebrandt : 144, pl. 14, figs. 3*a–c*.

DIAGNOSIS. A *Globorotalia* with small strongly umbilico-convex test ; flat, slightly imbricate dorsal side, and distinctly protruding ventral one ; extremely narrow umbilicus, and high umbilical shoulder ; curved, imbricate dorsal sutures, and radial, incised ventral ones ; crescentic chambers on dorsal side, elongated in direction of coiling and increasing rapidly in size ; delicate marginal keel, and delicately papillose surface.

DESCRIPTION. Test small, planoconvex, umbilico-convex, coiled in a very low trochospire; dorsal side flat, slightly imbricate ; ventral side distinctly protruding ; equatorial periphery roughly ovoid, distinctly lobate with a delicately beaded marginal keel ; axial periphery angular, acute ; chambers on the dorsal side about 12, rapidly increasing in size and arranged in 2½ dextrally coiled whorls ; the initial chambers are small, indistinct and almost masked by the surface rugosity ; the last whorl is composed of 3½, large, crescentic chambers, which are strongly elongated in the direction of coiling ; the last chamber constitutes about half the test ; on the ventral side, the chambers are 3½, distinctly angular conical, strongly protruding ; sutures on the dorsal side strongly curved, delicately beaded and very weakly raised ; on the ventral side they are almost straight, radial and strongly depressed ; umbilicus extremely small, deep and open ; aperture interiomarginal, extraumbilical-umbilical, a large, crescentic arch with a narrow delicate lip; wall calcareous perforate; surface delicately but distinctly papillose with the papillae decreasing gradually towards the last chamber.

DIMENSIONS OF HOLOTYPE.

Maximum diameter = 0·30 mm.
Minimum diameter = 0·22 mm.
Thickness = 0·20 mm.

REMARKS. *Globorotalia loeblichi* sp. nov. is morphologically similar to both *Globorotalia lensiformis* Subbotina, and *Globorotalia quetra* Bolli. It is distinguished from the former by its much smaller size, less tightly coiled test, fewer chambers in the last whorl, more lobate periphery, slightly imbricate dorsal side, less developed keel, and less rugose surface. It differs from *G. quetra* Bolli in its much smaller size ; flat, imbricate dorsal side ; less lobate periphery ; delicate, non-spinose keel, more angular axial periphery, and delicately papillose, non-spinose surface.

Loeblich & Tappan (1957*a*) described as *G. aequa* Cushman & Renz, from the Paleocene–Lower Eocene of the Gulf and Atlantic Coastal plains of the U.S.A., and of Mexico, forms with a marginal keel, although *G. aequa* does not have a keel. As can be seen from their figures, these forms probably belong to the present species, to *G. quetra* Bolli, and to other undescribed forms (see synonymy). Similarly, the form described by Said & Kerdany (1961) as *G. triplex* (Subbotina) is possibly *G. loeblichi* sp. nov.; *Acarinina triplex* is synonymous with both *Globigerina velascoensis* and *G. stonei*, as mentioned above. Again, although the holotype of *Acarinina pseudotopilensis* Subbotina is a junior synonym of *Globorotalia esnaensis* (Le Roy), the paratype figured by Subbotina (1953, pl. 22, figs. 1*a–c*) most probably belongs to the present species. Hillebrandt (1962) described as *Globorotalia* (*Truncorotalia*) *aequa simulatilis* (Schwager) and *Globorotalia* (*Acarinina*) *quetra* Bolli, forms which probably belong to *G. loeblichi*.

Globorotalia loeblichi sp. nov. is believed to have evolved from *G. aequa* Cushman & Renz by the development of a marginal keel, and by the reduction in the surface rugosity and in the size of the umbilicus. On the other hand it is believed to have evolved into *G. quetra* Bolli by the increase in the size of test; by the development of the slightly concave dorsal side, less tightly coiled test, distinctly spinose surface, spinose keel, and by the reduction of the keel on the last one or two chambers. The paratype figured by Bolli (1957*b*, pl. 19, figs. 4–6) is probably a transitional stage between *G. loeblichi* and *G. quetra*, and forms mentioned by Bolli as *G.* cf. *quetra* may belong to *G. loeblichi*.

The present species is named after Dr. A. R. Loeblich, Jr.

HOLOTYPE. P.45615.

PARATYPES. P.45669–70.

HORIZON AND LOCALITY. Holo- and paratypes, from sample No. 68, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globorotalia loeblichi* sp. nov. occurs in the uppermost Paleocene *G. aequa*/*G. esnaensis* Subzone and in the Lower Eocene *G. wilcosensis* Zone of the Esna–Idfu region.

Globorotalia nicoli Martin

1943 *Globorotalia nicoli* Martin : 27, pl. 7, figs. 3*a–c*.
? 1960 *Globorotalia convexa* Subbotina ; Olsson : 45, pl. 9, figs. 13–15.
1962 *Globorotalia nicoli* Martin ; Gartner & Hay : 565, pl. 11, figs. 3*a–c*.

REMARKS. This species is morphologically similar to both *G. convexa* Subbotina and *G. esnaensis* (Le Roy). It differs from the former in its slightly larger size, flatter dorsal side, fewer chambers per test and in the last whorl and in that its chambers are more strongly elongated in the direction of coiling. It is distinguished from *G. esnaensis* (Le Roy) by its smaller size, relatively compressed test, acute axial periphery and less lobate equatorial one, more strongly elongated chambers in the direction of coiling, slightly raised dorsal side and more tightly coiled test.

The forms described by Mallory (1959, pl. 30, figs. 7*a–c*) as *G. nicoli* Martin are different from Martin's original description and figures, while those figured by him (1959, pl. 42, figs. 4*a–c*) are possibly *G. convexa* Subbotina. Again, the forms figured by Olsson (1960) as *G. convexa* Subbotina are most probably *G. noicoli* Martin. *Globorotalia nicoli* is also morphologically similar to *G. aequa* Cushman & Renz, from which it probably evolved.

HYPOTYPE. P.45617.

HORIZON AND LOCALITY. Hypotype from sample No. 63, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *G. nicoli* was first described by Martin (1943) from the Paleocene–Lower Eocene Lodo Formation of California. It was also recorded from the Lower Eocene " marne bleue " of Mont Cayala, France, by Gartner & Hay (1962) who assigned it to the Ilerdian, and from the Paleocene Hornerstown formation, New Jersey coastal plain, by Olsson (1960).

In the Esna–Idfu region, *G. nicoli* occurs as a rare form in the uppermost Paleocene *G. aequa/G. esnaensis* Subzone.

Globorotalia occlusa Loeblich & Tappan

(Pl. 20, figs. 2*a–d* ; Pl. 22, figs. 4*a–c*)

1957*a* *Globorotalia occlusa* Loeblich & Tappan : 191, pl. 55, figs. 3*a–c* ; pl. 64, figs. 3*a–c*.
1960*b* *Globorotalia acutispira* Bolli & Cita : 15–17, pl. 33, figs. 3*a–c*.

DESCRIPTION. (Specimen, Pl. 22, figs. 4*a–c*.) Test medium sized umbilico-convex, coiled in a low trochospire ; dorsal side almost flat, very weakly raised in the centre ; ventral side distinctly protruding ; equatorial periphery roughly ovoid, very weakly lobate to almost entire, with a distinct, thin, marginal keel ; axial periphery sharply acute ; chambers on the dorsal side about 11 in number, arranged in 2 sinistrally coiled whorls ; the initial chambers are weakly raised, and almost masked by the surface texture ; the last whorl is composed of 5 large, roughly crescentic chambers, which are strongly elongated in the direction of coiling, and increase gradually in size (however, the last chamber is broken in the figured specimen and the penultimate chamber is slightly smaller than the ante-penultimate) ; on the ventral side the chambers are 5 (4 + 1 broken), large, angular, conical, roughly triangular, distinctly protruding with their distal ends moderately decorated with fine papillae and approaching very closely around the much narrowed umbilicus; sutures on the dorsal side curved, moderately raised and delicately beaded ; on the ventral side they are radial and strongly depressed ; umbilicus very small, deep, open, and surrounded with a small, thickened and papillose umbilical shoulder ; aperture interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface delicately papillose in the early part, smooth later, except for the papillose umbilical shoulder, dorsal sutures, marginal keel, and the early chambers on the ventral side where the beads sometimes taper out in the form of delicate spines, giving the surface a roughly hirsute appearance.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter	=	0·41 mm.
Minimum diameter	=	0·34 mm.
Thickness	=	0·24 mm.

REMARKS. *Globorotalia occlusa* was first described by Loeblich & Tappan from the Velasco formation of Mexico. These authors (1957*a*, pl. 45, figs. 7*a–c*, pl. 50, figs. 4*a–c*), also described as *G. angulata* (White), forms which most probably belong to *G. occlusa*.

Bolli & Cita (1960*b*) described as *G. acutispira* a form which only differs from the present species in being slightly more lobate : it is thus included in the synonymy.

Hillebrandt (1962) considered *G. occlusa* as a subspecies of *G. velascoensis*, but the present study showed clearly that the two species should be considered separately in spite of their morphological similarity.

Globorotalia occlusa is distinguished by its medium-sized, umbilico-convex test ; weakly curved dorsal side and protruding ventral side ; its very narrow, deep umbilicus ; papillose umbilical shoulder, thin, papillose or even hirsute keel ; slightly rough early part ; curved, raised, delicately beaded dorsal sutures and radial strongly depressed, ventral ones. It is believed to have evolved from *G. angulata* (White) as indicated by their morphological characters and stratigraphical distribution, although no direct evidence was recorded. On the other hand, *G. occlusa* is morphologically somewhat similar to *G. aragonensis* Nuttall, which may be among its direct or indirect descendants.

Globorotalia occlusa is also morphologically similar to *G. simulatilis* (Schwager), although very little is known about this form. However, *G. occlusa* has a distinctly developed marginal keel, while Schwager (1883) in his original description of *Discorbina simulatilis* stated that " the test is somewhat drawn out towards the periphery, but in no way really keeled ". Nevertheless, Said (1960) described as *G. simulatilis* (Schwager) from the " Esna shales " of Luxor section, Egypt, a form with a distinctly developed marginal keel as can be seen from his figures. This form is possibly *G. subbotinae* Morozova. Said relied on his study (Said & Kerdany 1961) of supposed topotype material of Schwager's species, but the form figured by these authors also has a distinct marginal keel. It was described from the Upper Paleocene *G. velascoensis* Zone while Schwager's holotype is from the Lower Eocene " Libysche Stufe ".

HYPOTYPES. P.45618–19.

HORIZON AND LOCALITY. Figured specimens, Pl. 20, figs. 2*a–d*, Pl. 22, figs. 4*a–c*, from samples No. 40 and 51 respectively, Gebel Owaina section.

STRATIGRAPHICAL RANGE. Loeblich & Tappan (1957*a*) described the holotype of *G. occlusa* from the Paleocene Velasco formation of Mexico. They also recorded the species from the Upper Landenian (Sparnacian) Vincentown formation of New Jersey, Salt Mountain limestone of Alabama and the Aquia formation of Virginia.

Bolli & Cita (1960*b*) described this species under the name *G. acutispira* from the *G. pseudomenardii* – *G. velascoensis* Zones of the Paderno d'Adda section of northern Italy which were regarded by them as Montian–Thanetian.

Hillebrandt (1962) recorded this species to range throughout his Lower, Middle and Upper Paleocene of Austria, which he regarded as Montian, Landenian and Ilerdian respectively, although his forms appear to be different from Loeblich & Tappan's original description and figures.

In the Esna–Idfu region *G. occlusa* appears in the Upper Paleocene *G. velascoensis* Zone. It floods the basal part of this zone, the *G. pseudomenardii* Subzone and fades out gradually upwards in the section, dying out completely in the overlying *G. aequa–G. esnaensis* Subzone.

Globorotalia perclara Loeblich & Tappan
(Pl. 21, figs. 2*a–c*)

1957*a* *Globorotalia perclara* Loeblich & Tappan : 191–192, pl. 40, figs. 7*a–c* ; pl. 41, figs. 8*a–c* ; pl. 42, figs. 4*a–c* ; pl. 45, figs. 11*a–c* ; pl. 46, figs. 3*a–c* ; pl. 47, figs. 6*a–c* ; pl. 50, figs. 1*a–c* ; pl. 54, figs. 6*a*–7*c* ; pl. 57, figs. 3*a*–4*c* ; pl. 60, figs. 5*a–c*.

1960 *Globorotalia perclara* Loeblich & Tappan ; Olsson : 46, pl. 9, figs. 1–3.

DESCRIPTION. Test large, moderately inflated, coiled in a low trochospire ; dorsal side almost flat, slightly imbricate in the early part, becoming gradually inflated towards the last chamber ; ventral side moderately inflated although the first two chambers are slightly flattened ; equatorial periphery roughly ovoid, elongate, distinctly lobate ; axial periphery rounded ; chambers on the dorsal side 16, arranged in 3 dextrally coiled whorls ; the initial chambers are small, slightly flattened, increasing slowly in size and are followed by relatively larger, quadrangular chambers which become crescentic towards the beginning of the last whorl, and increase moderately in size ; the last whorl is composed of 6 large chambers which are crescentic, imbricate and slightly compressed in the early part, globular and inflated later, and increase moderately in size ; on the ventral side there are 6 large chambers which increase gradually in size and degree of inflation ; sutures on the dorsal side curved, depressed in the early part, becoming almost straight, radial and strongly depressed later ; on the ventral side the sutures are straight, radial and strongly incised ; umbilicus small, deep and open ; aperture a long, crescentic arch, interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface on the dorsal side rough, papillose in the early part, smooth to very delicately papillose later, heavily nodose on the ventral side.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·44 mm.
Minimum diameter = 0·32 mm.
Thickness = 0·25 mm. (of last chamber)

REMARKS. *Globorotalia perclara* was first described by Loeblich & Tappan (1957*a*) from the Paleocene of the Gulf and Atlantic Coastal Plains. These authors also considered the form previously described by Shifflett (1948) as *Globigerina* cf. *pseudobulloides* Plummer, from the Aquia formation of Virginia, to belong to the present species. The specimens figured by Berggren (1960*a*) as *G. perclara* are completely different from the types and should be considered separately.

Globorotalia perclara is distinguished by its small to large, elongate test; its tightly coiled, compressed early part, and globular, inflated later part; its distinctly nodose, spinose ventral side, and almost smooth last chambers and rough early ones on the dorsal side ; its curved dorsal sutures which are depressed in the early part, and which become straight, radial, strongly depressed later ; its radial, strongly incised ventral sutures ; its curved spiral suture which becomes strongly depressed in the later part ; its narrow, deep umbilicus and its characteristic aperture.

The species is morphologically similar to *G. uncinata uncinata* (Bolli) from which it is distinguished by its radial, depressed intercameral sutures, which are curved and depressed in *G. uncinata*, its roughly spinose ventral side, its less tightly coiled test, compressed early part and inflated later part, and its wider umbilicus. *Globorotalia uncinata* was only recorded from the lower part of the Middle Paleocene while *G. perclara* ranges throughout the whole Paleocene. Berggren (1960*a*) stated that further study may reveal these two forms to be conspecific, but the present study strongly substantiates their separate identity.

Globorotalia perclara probably evolved from *G. trinidadensis* Bolli by the reduction in the size of test, the flattening of the early part and the development of the surface rugosity although no direct evidence was recorded. On the other hand, it is believed to have evolved into *G. sibaîyaensis* sp. nov. by the further reduction in the size of test, and the development of an entire, heavily spinose surface. The morphological features and stratigraphical ranges of these species support this suggestion.

HYPOTYPE. P.45620.

HORIZON AND LOCALITY. Figured specimen, from sample No. 35, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was first described by Loeblich & Tappan (1957*a*) from the Danian Brightseat formation of Alabama and was reported to range throughout the Paleocene and the Lower Eocene of the Gulf and Atlantic Coastal Plains, U.S.A. However, the Nanafalia formation of Alabama, which they considered as Lower Eocene, was regarded by Bramlette & Sullivan (1961) and Gartner & Hay (1962) to belong to the Paleocene. The species was also recorded by Olsson (1960) from the Hornerstown formation of New Jersey and was observed in the Noxontown fauna by the same author.

In the Esna–Idfu region, *G. perclara* ranges throughout most of the Paleocene, being common to flood in the Lower and Middle Paleocene, and rare in the Upper Paleocene. It dies out completely in the lower part of the *G. aequa–G. esnaensis* Subzone.

Globorotalia pseudobulloides (Plummer)

(Pl. 18, figs. 3*a*–*c*)

1926 *Globigerina pseudobulloides* Plummer : 133–134, pl. 8, figs. 9*a*–*c*.

1937*b* *Globigerina pseudobulloides* Plummer ; Glaessner : 382, pl. 4, figs. 31*a*–*c*.

1940 *Globigerina pseudobulloides* Plummer ; Cushman : 72, pl. 12, figs. 16*a*, *b*.

1942 *Globigerina pseudobulloides* Plummer ; Cushman & Todd : 43, pl. 8, figs, 3, 4.

1949 *Globorotalia* (*Globorotalia*) *compressa* (Plummer) ; Cushman & Bermudez : 34–35, pl. 6, figs. 19–21.

1949 *Globigerina* cf. *pseudobulloides* Plummer ; Cushman & Stone : 57, pl. 10, fig. 15.

1951 *Globigerina pseudobulloides* Plummer : Cushman : 60, pl. 17, figs. 7, 8.

1953 *Globigerina compressa* Plummer var. *compressa* Plummer ; Subbotina (pars) : 55, pl. 2, figs. 3*a*–5*c*, ? figs. 2*a*–*c*, non figs. 6*a*–*c*.

1953 *Globigerina compressa* Plummer var. *pseudobulloides* Plummer ; Subbotina : 57, pl. 2, figs. 7*a*–14*c*.

1953 *Globigerina varianta* Subbotina (pars) : 63, pl. 3, figs. 5*a*–7*c*, 10*a*–12*c* ; pl. 4, figs. 1*a*–3*c* ; pl. 15, figs. 1*a*–3*c* ; non pl. 3, figs. 8*a*–9*c*.
1953 *Globigerina pseudobulloides* Plummer ; Hamilton : 223, pl. 31, figs. 10, 11.
1955 *Globigerina pseudobulloides* Plummer ; Dalbiez & Glintzboeckel (*in* Cuvillier *et al.*, 1955) : 533, 534, 536, pl. 1, figs. 1*a*–*c*.
1957*b* *Globorotalia pseudobulloides* (Plummer) Bolli : 73, pl. 17, figs. 19–21.
1957 *Globigerina pseudobulloides* Plummer ; Troelsen (pars) : 128, pl. 30, figs. 6*a*–7*c*, non figs. 8*a*–*c*.
1957*a* *Globorotalia pseudobulloides* (Plummer) ; Loeblich & Tappan (pars) : 192, pl. 40, figs. 3*a*–*c*, 9*a*–*c* ; pl. 42, figs. 3*a*–*c* ; pl. 43, figs. 3*a*–4*c* ; pl. 44, figs. 6*a*–*c*, non figs.4, 5 ; pl. 45, figs. 1*a*–2*c* ; pl. 46, figs. 6*a*–*c*.
1957 *Globigerina pseudobulloides* Plummer ; Sacal & Debourle : 55, pl. 23, fig. 2.
1957*a* *Globigerina pseudobulloides* Plummer ; Hofker ; 57, text-figs. 8*a*–*c*.
? 1959*e* *Globigerina pseudsbulloides* Plummer ; Hofker (pars) : 80–83, ? text-figs. 1*a*–2*c*, non text-figs. 3*a*–5*c*.
? 1959 *Globigerina pseudobulloides* Plummer ; Hamilton & Rex : 791, pl. 252, fig. 3.
1959 *Globigerina pseudobulloides* Plummer : Nakkady : 461, pl. 3, figs. 4*a*–*c*.
1960 *Globorotalia pseudobulloides* (Plummer) ; Olsson : 46, pl. 9, figs. 19–21.
1960 *Globorotalia pseudobulloides* (Plummer) ; Bolli & Cita ; 25–26, pl. 31, figs. 4*a*–*c*.
1960*b* *Globorotalia pseudobulloides* (Plummer) ; Reyment (pars) : 84, pl. 15, figs. 18*a*, *b* ; non pl. 16, figs. 2, 3.
1960*a* *Globigerina pseudobulloides* Plummer ; Hofker (pars) : 232, text-figs. 31*a*–*c*, 33*a*–*c* ; non figs. 26*a*–*c*.
1960*d* *Globigerina pseudobulloides* Plummer ; Hofker : 35, pl. 1, fig. A ; pl. 2, fig. A.
1960*g* *Globigerina pseudobulloides* Plummer ; Hofker : 77–78, figs. 17*a*–20*c*, 22*a*–*c*, 23*a*–*c*, 36*a*–38*c*.
? 1960*g* *Globigerina triloculinoides* Plummer ; Hofker (pars) : text-figs. 21*a*–*c*, ? 24*a*–*c*, non 26*a*–28*c*.
1960*i* *Globigerina pseudobulloides* Plummer ; Hofker (pars) : 120, pl. 2, figs. 2–5, non fig. 6.
1960 *Globigerina bulloides* d'Orbigny ; Vinogradov : 307, pl. 2, figs. 12*a*–13*c*.
1961 *Globigerina pseudobulloides* Plummer ; Bermudez : 1.194, 1.195, pl. 5, figs. 4*a*–*b*.
1961 *Globorotalia varianta* (Subbotina) ; Said & Kerdany : 330, pl. 1, figs. 4*a*–*c*.
1961*a* *Globigerina pseudobulloides* Plummer ; Hofker : 69–71, pl. 1, figs. 2208, 2199, 2211, 2212, 2220.
1962 *Globorotalia* (*Turborotalia*) *pseudobulloides* (Plummer) ; Berggren (pars) : 87–93, pl. 14, figs. 3*a*–4*c* ; text-figs. 12 (1*a*–3*b* ; non 4*a*–*b* ; 5*a*–7*b*).
1962 *Globorotalia* (*Globorotalia*) *pseudobulloides* (Plummer) ; Hillebrandt : 124—25, pl. 12, figs. 2*a*–*c*.

DESCRIPTION. Test medium sized, globigerine, coiled in a very low trochospire ; dorsal side inflated with the initial whorls slightly raised ; ventral side strongly inflated ; equatorial periphery nearly ovoid and distinctly lobate ; axial periphery broadly rounded ; chambers 15, arranged in 3 dextrally coiled whorls ; the initial chambers are very small, inflated, globigerine and increase very slowly in size ; the last whorl is composed of 4½ large, globular, strongly inflated chambers, which increase so rapidly in size that the penultimate and last chambers constitute most of the test ; on the ventral side the chambers are 4½, large, globular, strongly inflated and increase rapidly in size ; sutures on the dorsal side curved, depressed in the early part, nearly straight, radial and depressed later ; on the ventral side the sutures are radial and strongly depressed ; umbilicus irregular in outline, narrow, deep and open ; aperture interiomarginal, extraumbilical-umbilical, in the form of a large rounded opening bordered above by a narrow delicate lip ; wall calcareous, distinctly perforate ; surface very finely pitted.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·41 mm.
Minimum diameter = 0·22 mm.
Thickness = 0·26 mm.

MAIN VARIATION.

1. Chambers 12–15, arranged in 2½–3 whorls.
2. Coiling predominantly dextral (of 240 specimens picked at random, 62 coiled sinistrally).
3. Chambers in the last whorl 4½–5, rarely 5½.
4. The surface is usually finely pitted, but in some specimens the pits become coarser.

REMARKS. Bolli (1957*b*) removed this species from *Globigerina* to *Globorotalia* because of the extraumbilical-umbilical position of the aperture. This was substantiated by Loeblich & Tappan (1957*a*), Olsson (1960), Bolli & Cita (1960*b*), Reyment (1960), Berggren (1962) and Hillebrandt (1962). The subgeneric classification adopted by the last two authors is not followed here for reasons already explained.

G. pseudobulloides (Plummer) is distinguished by its low, trochospirally coiled, " globigerine " test ; its slightly raised initial spire ; its 4½–5 chambers in the last whorl which are strongly inflated and increase very rapidly in size ; its large, strongly inflated last chamber ; strongly incised sutures and finely reticulate surface.

Subbotina (1953) confused *G. pseudobulloides* with *Globorotalia compressa* (Plummer) and considered the former as a variety of the latter. However, both her *Globigerina compressa* var. compressa Plummer and *Globigerina compressa* var. *pseudobulloides* Plummer are mostly *G. pseudobulloides* (Plummer). Contrary to Subbotina's observations *G. pseudobulloides* and *G. compressa* are two distinct species. Subbotina also described as *Globigerina varianta* n.sp., forms which probably belong to *G. pseudobulloides* (Plummer), *Globorotalia quadrata* (White) and *Globorotalia esnaensis* (Le Roy).

Hofker (1960*g*, *i*) studied the orthogenetic changes in the development of *G. pseudobulloides* in the type Danian, the Paleocene rocks of Denmark, and the uppermost white chalk of Holland and Belgium. Although he confused the present species with apparently similar *Hedbergella* species in the Maestrichtian rocks below and considered it to belong to the genus *Globigerina* it is of interest to review his observations.

Hofker (1960*g* ; 78) stated that " . . . . . this species, beginning in the uppermost white chalk (Skrivekridt) with knobs between the fine pores, gradually changes its wall structure through the Danian from a pitted one towards a strongly honeycombed one in the Paleocene clays above the greensand, indicating that those clays are of the same age as the Midway Paleocene " However, as the Lower and Middle Danian are missing in the sections studied, it was not possible to judge the suggestions of Hofker (1960*g*, *i*) which were partially substantiated by Berggren (1962), that typical *G. pseudobulloides* had evolved from a smooth, finely perforate test. Nevertheless, a slight tendency towards an increase in the surface reticulation of test upwards in the section, was observed in the specimens studied.

On the other hand, *G. pseudobulloides* is believed to have evolved in several directions, leading to *Globorotalia compressa* (Plummer), *G. imitata* Subbotina, *G. quadrata* (White), *G. trinidadensis* Bolli, *G. tribulosa* Loeblich & Tappan and *Globigerina triloculinoides* Plummer (see discussion under these species and Text-fig. 15).

HYPOTYPE. P.45621.

HORIZON AND LOCALITY. Figured specimen, from sample No. 38, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species was first described from the Midway group of Texas, which, according to Loeblich & Tappan (1957*a*, *b*), is of Danian age.

All reliable records show that *G. pseudobulloides* (Plummer) ranges throughout the Lower and Middle Paleocene with a rare occurrence in the basal part of the Upper Paleocene. All records of the species in rocks older than the Danian or younger than the lower part of the upper Paleocene are erroneous.

G. pseudobulloides is recorded as ranging throughout the whole Danian at its type locality in Denmark, being common at the base, and less common towards its top (Brönnimann 1953 ; Troelsen 1957 ; Loeblich & Tappan 1957*a*, *b* ; Berggren 1960*b*, 1962 and Hofker 1960*g*, *i*).

Haynes (1955, 1956) recorded this species from the type Thanetian of England, and it was recently identified by the writer from Thanetian samples kindly provided by Dr. Haynes, and from samples collected by the author ; although the form figured by Haynes (1956, pl. 17, figs. 12, 12*b*) as *Globigerina pseudobulloides* Plummer is an Upper Cretaceous *Rugoglobigerina* species redeposited in the type Thanetian, as examination of his specimens (B.M.N.H., P. 42633) has revealed.

In the Esna–Idfu region, *G. pseudobulloides* (Plummer) floods the Lower and Middle Paleocene parts of the sections studied, and dies out completely in the basal part of the Upper Paleocene *G. velascoensis* Zone.

Globorotalia pseudomenardii Bolli

(Pl. 17, figs. 7*a*–8*c*)

1926 *Pulvinulina membranacea* (Ehrenberg) ; Cushman : 608, pl. 21, fig. 10.
? 1928*b* *Globorotalia membranacea* (Ehrenberg) White : 280–281, pl. 38, figs. 1*a*–*c*.
? 1941 *Globorotalia membranacea* (Ehrenberg) ; Toulmin : 608, pl. 82, figs. 4, 5.
? 1944 *Globorotalia membranacea* (Ehrenberg) ; Applin & Applin : pl. 5, fig. 2.
? 1946 *Globorotalia membranacea* (Ehrenberg) ; Cushman & Renz : 48, pl. 8, figs. 15, 16.
1949 *Globorotalia* cf. *membranacea* (Ehrenberg) ; Cushman & Stone : 57, pl. 10, figs. 16*a*, *b*.
1953 *Globorotalia membranacea* (Ehrenberg) ; Subbotina (pars) : 205, pl. 16, fig. 13, non figs. 7–12.
1955*b* *Globorotalia* cf. *membranacea* (Ehrenberg) ; Weiss : 309, pl. 12, figs. 4, 5.
1955 *Globorotalia membranacea* (Ehrenberg) ; Dalbiez & Glintzboeckel (*in* Cuvillier *et al.*, 1955) : 534, pl. 1, figs. 5*a*–*c*.
1956 *Globorotalia membranacea* (Ehrenberg) ; Haque : 188–189, pl. 22, figs. 3*a*–*c*.

1957*b* *Globorotalia pseudomenardii* Bolli : 77, pl. 20, figs. 14–17.
? 1959 *Globorotalia pseudomenardii* Bolli ; Nakkady : 462–463, pl. 4, figs. 3*a–c*.
1960*b* *Globorotalia pseudomenardii* Bolli ; Bolli & Cita : 26–27, pl. 33, figs. 2*a–c*.
1961 *Globorotalia pseudomenardii* Bolli ; Said & Kerdany : 329, pl. 1, figs. 5*a–c*.
? 1961 *Globorotalia pseudomenardii* Bolli ; Bermudez : 1,298–1, 300, pl. 15, fig. 9.
? 1962 *Globorotalia pseudomenardii* Bolli ; Hillebrandt : 126–127, pl. 12, figs. 5*a–c*, 6*a*, *b*.

DESCRIPTION. (Specimen, Pl. 17, figs. 7*a–c*.) Test small, weakly biconvex, compressed, coiled in a low trochospire ; dorsal side slightly raised, ventral side moderately inflated ; equatorial periphery roughly ovoid, elongate, distinctly lobate ; axial periphery angular, sharply acute, pinched out, with a fine, but distinct, entire keel ; chambers, 12, arranged in 2 sinistrally coiled whorls ; the initial chambers are small, slightly inflated, globigerine and increase slowly in size ; the last whorl is composed of 5, roughly lenticular, weakly inflated, compressed chambers which increase very rapidly in size ; on the ventral side, the 5, roughly lenticular chambers are moderately inflated ; sutures on the dorsal side strongly curved, depressed ; on the ventral side they are almost straight, radial and strongly depressed ; umbilicus small, shallow and open ; aperture interiomarginal, extraumbilical-umbilical, a long narrow arch covered by a delicate, flaring lip ; wall calcareous, perforate ; surface smooth.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter	=	0·30 mm.
Minimum diameter	=	0·20 mm.
Thickness	=	0·14 mm. (of last chamber)

MAIN VARIATION.

1. Chambers 12–18, arranged in 2–3 whorls.
2. Coiling predominantly sinistral (of 125 specimens picked at random, 79 coiled sinistrally).
3. Chambers in the last whorl 4–6, most commonly 5.

REMARKS. This species was quite often described in the past as *G. membranacea* (Ehrenberg), a *nomen nudum*. It is distinguished by its smooth, weakly biconvex, compressed, elongate test ; its fine, entire keel ; distinctly acute axial periphery; curved, depressed dorsal sutures and radial, incised, ventral ones ; its small umbilicus ; narrow elongate aperture, and delicate flaring lip.

Loeblich & Tappan (1957*a*) described as *G. pseudomenardii* Bolli, forms which are completely different from the type specimens of Bolli and from the known hypotypes, while the form described by Olsson (1960) is most probably *G. emilei* sp. nov.

Globorotalia pseudomenardii is believed to have evolved from *G. ehrenbergi* Bolli in earliest Upper Paleocene time by the development of the entire keel, the rapidly increasing chambers in the last whorl, and the distinctly acute, pinched-out axial periphery ; although its evolution from *G. emilei* into *G. woodi* is not excluded.

HYPOTYPES. P.45622.

HORIZON AND LOCALITY. Figured specimens, from sample No. 39, Gebel Owaina section.

Stratigraphical range. The species was first described by Bolli (1957*b*) from the Paleocene lower Lizard Springs formation of Trinidad, where it characterizes the *G. pseudomenardii* Zone, to which it is restricted. Bolli did not relate his faunal zones to any classification of the Paleocene, but Bolli & Cita (1960*a*, *b*) considered the *G. pseudomenardii* Zone of the Paderno d'Adda section of northern Italy to be of Upper Montian age. Reliable records show that *G. pseudomenardii* is of lower Upper Paleocene age. All records of this species from strata younger or older than the lower Upper Paleocene (e.g. Loeblich & Tappan 1957*a*) are erroneous.

In the Esna–Idfu region *Globorotalia pseudomenardii* Bolli appears with the first representatives of *G. velascoensis velascoensis* (Cushman) in the basal part of the *Globorotalia velascoensis* Zone. It floods the lower part of this zone, thus defining the *G. pseudomenardii* Subzone, here considered to be of lower Upper Paleocene age; it dies out before the first appearance of *G. esnaensis* and *G. aequa* which characterize the overlying subzone.

Globorotalia pusilla laevigata Bolli
(Pl. 17, figs. 12*a*–*c*)

1957*b* *Globorotalia pusilla laevigata* Bolli : 78, pl. 20, figs. 5–7.
1960*b* *Globorotalia pusilla laevigata* Bolli ; Bolli & Cita : 27–28, pl. 32, figs. 6*a*–*c*.
1962 *Globorotalia* (*Globorotalia* ?) *pusilla laevigata* Bolli ; Hillebrandt : 128–129, pl. 11, figs. 17*a*, *b*.

Description. Test small, roughly lenticular, coiled in a very low trochospire ; dorsal side slightly raised, gently convex ; ventral side strongly convex, moderately protruding ; equatorial periphery circular, slightly lobate ; axial periphery acute, with a very thin, faintly developed, delicately beaded marginal keel ; chambers 19, arranged in 3, sinistrally coiled whorls ; the inital ones are very small, slightly inflated, globigerine, and are followed by relatively large, almost crescentic, overlapping chambers which increase slowly in size except for the last, which is often slightly smaller than the penultimate ; the last whorl is composed of 6, large, roughly crescentic chambers which increase slowly in size ; on the ventral side the chambers are 6, relatively large, roughly triangular, conical, inflated, almost equal in size ; sutures on the dorsal side strongly curved, faintly raised and very delicately beaded ; on the ventral side they are almost straight, radial and depressed ; umbilicus small, shallow and open ; aperture an elongated arch, covered by a prominent, delicate lip, interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface smooth or very delicately papillose.

Dimensions of described specimen.

Maximum diameter = 0·30 mm.
Minimum diameter = 0·26 mm.
Thickness = 0·16 mm.

Main variation.

1. Chambers 12–18, arranged in 2½–3 whorls.
2. Coiling tends to be dextral (of 15 specimens picked at random, 11 coiled dextrally).

3. The last whorl is usually composed of 5–6 chambers, but 4 or 7 are sometimes found.

REMARKS. *Globorotalia pusilla laevigata* is characterized by its small, roughly lenticular test ; strongly protruding ventral side ; acute axial periphery ; weakly developed keel ; strongly curved, slightly raised dorsal sutures, and radial, depressed ventral ones ; its crescentic chambers which increase slowly in size on the dorsal side, and its triangular, conical, strongly protruding ones on the ventral ; its small umbilicus ; characteristic aperture and smooth to delicately papillose surface.

Loeblich & Tappan (1957*a* : 194) mentioned that *G. pusilla laevigata* is very similar and undoubtedly related to *G. pseudoscitula* Glaessner. However, although they did not include it in the synonymy of the latter, they described as *G. pseudoscitula*, forms which most probably belong to *G. pusilla laevigata*. These authors (pl. 45, figs. 7*a–c*) also described, as *G. angulata* (White), a form with a faintly developed keel, which is most probably a 4-chambered *G. pusilla laevigata*.

As previously mentioned by Bolli (1957*b*) *G. pusilla laevigata* is believed to have evolved from *G. pusilla pusilla* ; transitional stages between these two subspecies were recorded, and their stratigraphical distribution substantiates this suggestion.

HYPOTYPE. P.45623.

HORIZON AND LOCALITY. Figured specimen, from sample No. 48, Gebel Owaina section.

STRATIGRAPHICAL RANGE. Bolli (1957*b*) described *G. pusilla laevigata*, from the Paleocene, lower Lizard Springs formation of Trinidad, where he showed it to range through his *G. pseudomenardii* Zone only. It was also recorded from the same zone of the Paderno d'Adda section of Northern Italy (Bolli & Cita 1960*a*, *b*). Hillebrandt (1962) extended its range to cover strata which he referred to the Lower and Middle Paleocene (Montian–Landenian) of Austria. Some of the specimens which Loeblich & Tappan (1957*b*) described under *G. pseudoscitula* Glaessner and *G. angulata* (White), from the Landenian of the Gulf and Atlantic Coastal Plains, probably represent this subspecies.

In the Esna–Idfu region, *G. pusilla laevigata* appears in the basal part of the Upper Paleocene *G. velascoensis* Zone. It continues as a common form in the lower part of this zone, the *G. pseudomenardii* Subzone, and fades out gradually, dying out completely in the basal part of the overlying *G. aequa*/*G. esnaensis* Subzone.

Globorotalia pusilla mediterranica subsp. nov.

(Pl. 19, figs. 3*a–c*)

DIAGNOSIS. A *Globorotalia pusilla* with relatively larger, papillose test ; more chambers and whorls ; more protruding ventral side and moderately convex dorsal one ; roughly quadrangular last chambers on dorsal side, very narrow and very strongly elongated in direction of coiling ; very high, angular conical chambers on ventral side, strongly protruding from the periphery, leaving it as a thick, marginal pseudo-keel.

DESCRIPTION. Test medium-sized, unequally biconvex, coiled in a low trochospire; dorsal side moderately convex, ventral side strongly and distinctly protruding; equatorial periphery almost circular, moderately lobate ; axial periphery acute, without keel, but the chambers on the ventral side are so strongly protruding that the marginal periphery appears as if separated from this protruding mass by a very shallow groove in the form of a thick marginal pseudo-keel ; chambers on the dorsal side 18, arranged in 3½ dextrally coiled whorls ; the initial ones are small, inflated, globigerine, almost masked by the surface rugosity and are followed by crescentic, elongated chambers; the last whorl is slightly lower than the preceding whorls, and is composed of 4½, long, narrow, roughly quadrangular chambers, which are strongly elongated in the direction of coiling and increase slowly in size ; on the ventral side the chambers are 4½, large, roughly triangular, conical, moderately inflated and distinctly protruding ; sutures on the dorsal side curved, depressed in the early part, very short, slightly curved and depressed later ; on the ventral side the sutures are straight, radial and strongly incised ; umbilicus relatively small, deep and open ; aperture interiomarginal, extraumbilical-umbilical, a narrow, long arch, with a delicate, narrow lip ; wall calcareous perforate ; surface distinctly papillose, especially in the early part.

DIMENSIONS OF HOLOTYPE.

Maximum diameter = 0·35 mm.
Minimum diameter = 0·30 mm.
Thickness = 0·29 mm.

REMARKS. *Globorotalia pusilla mediterranica* has all the main characteristics of the *G. pusilla* group : the biconvex, strongly inflated test ; the protruding ventral side, with its triangular, conical, high chambers ; radial, depressed ventral sutures ; small umbilicus ; and long, narrow, arched aperture, with an occasional delicate apertural lip. It is thus included as a subspecies of *G. pusilla*, although it is quite distinct from the other two subspecies, *G. pusilla pusilla* and *G. pusilla laevigata*. It differs from the former in protruding more on the ventral side, in having a higher umbilical shoulder, a thick, marginal pseudo-keel, and quadrangular chambers on the dorsal side. From the latter it is distinguished by its more convex dorsal side, greater protrusion of the ventral surface, its thick marginal pseudo-keel, rough surface, and the shape of the chambers on the dorsal side.

Globorotalia pusilla mediterranica is believed to have evolved from *G. pusilla pusilla*, but nothing is known as yet about its evolution in younger strata, as no morphologically similar forms have so far been described.

HOLOTYPE. P.45624.

PARATYPES. P.45625.

HORIZON AND LOCALITY. Holo- and paratypes, from sample No. 37, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globorotalia pusilla mediterranica* appears in the upper part of the *G. pusilla* Subzone of upper Middle Paleocene age. It continues as a rare to common form in the overlying *G. pseudomenardii* Subzone, and dies out in the basal part of the Upper Paleocene *G. aequa*/*G. esnaensis* Subzone.

Globorotalia pusilla pusilla Bolli

(Pl. 17, figs. 11*a*–*c*)

1957*b* *Globorotalia pusilla pusilla* Bolli : 78, pl. 20, figs. 8–10.
1960*b* *Globorotalia pusilla pusilla* Bolli ; Bolli & Cita : 28–29, pl. 32, figs. 4*a*–*c*.
1962 *Globorotalia* (*Globorotalia* ?) *pusilla pusilla* Bolli ; Hillebrandt : 128, pl. 11, figs. 18*a*, *b*.

DESCRIPTION. Test small, biconvex, coiled in a low trochospire ; dorsal side moderately convex, inflated, slightly imbricate ; ventral side convex, inflated, moderately protruding ; equatorial periphery nearly circular, moderately lobate ; axial periphery subacute, without keel ; chambers on the dorsal side 17, arranged in 3 dextrally coiled whorls ; the initial ones are small, inflated, globigerine, and are followed by typically crescentic inflated, strongly imbricating chambers which increase moderately in size ; the last whorl is composed of 5, large, typically crescentic, slightly inflated, strongly imbricating chambers which are elongated in the direction of coiling ; on the ventral side the chambers are 5, large, roughly triangular and moderately inflated ; sutures on the dorsal side strongly curved, depressed ; on the ventral side they are almost straight, radial and depressed ; umbilicus small, shallow and open ; aperture interiomarginal, extraumbilical-umbilical, a long, narrow arch, with a narrow delicate lip ; wall calcareous, perforate ; surface smooth.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter	=	0·31 mm.
Minimum diameter	=	0·26 mm.
Thickness	=	0·19 mm.

MAIN VARIATION.

1. Chambers 12–18, arranged in 2½–3 whorls ; compressed to slightly inflated.
2. Coiling fairly random, with a tendency to be dextral (of 126 specimens picked at random, 78 coiled dextrally).
3. Chambers in the last whorl 4–6, most commonly 5.
4. The surface is generally smooth, but a few forms with a finely hispid surface were also recorded and are considered to be transitional to *G. convexa* Subbotina.

REMARKS. *Globorotalia pusilla pusilla* is distinguished by its small, biconvex, smooth test ; crescentic, imbricate chambers on the dorsal side, and triangular, inflated ones on the ventral ; its subacute axial periphery ; curved, depressed dorsal sutures, and radial, strongly incised ventral ones ; its small umbilicus and narrow, long aperture.

The ancestral stock from which this species evolved is not really known. However, its evolution from forms such as *G. uncinata uncinata* Bolli or its descendant *G. angulata angulata* (White) is possible, although no direct evidence was recorded. On the other hand, *G. pusilla pusilla* is believed to have evolved in two directions ; one leading to *G. pusilla laevigata* Bolli, by the slight flattening of the dorsal side, the development of an acute axial periphery and a partially or completely developed keel; the other to *G. pusilla mediterranica* subsp. nov. by the increase in the size of test, greater protrusion of the ventral side, the development of quadrangular chambers on the dorsal side, the pseudo-keel and the surface rougosity. Moreover, *G. convexa* Subbotina might possibly have evolved from *G. pusilla pusilla* by reduction in the size of test, development of surface spines and the bulla-like last chamber.

HYPOTYPE. P.45626.

HORIZON AND LOCALITY. Figured specimen, from sample No. 37, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globorotalia pusilla pusilla* was first described by Bolli (1957*b*) from the Paleocene lower Lizard Springs formation of Trinidad, where it characterizes the *G. pusilla pusilla* Zone, and continues through the lower part of the overlying *G. pseudomenardii* Zone. It is also recorded from the so-called Lower Montian of northern Italy (Bolli & Cita 1960*a*, *b*) and Montian of Austria (Hillebrandt 1962).

In the Esna–Idfu region, *G. pusilla pusilla* appears in the uppermost part of the *G. uncinata* Subzone, and continues in the basal part of the *G. pseudomenardii* Subzone where it dies out completely. Between the limits of these two subzones it floods the succession, thus characterizing the *G. pusilla* Subzone, of upper Middle Paleocene age.

Globorotalia quadrata (White)
(Pl. 18, figs. 4*a–c*)

1928*a* *Globigerina quadrata* White : 195, pl. 27, figs. 18*a*, *b*.
1957*b* *Globorotalia quadrata* (White) Bolli : 73–74, pl. 17, figs. 22–24.
1959 *Globigerina quadrata* White ; Nakkady (pars) : 461, pl. 3, figs. 3*a–c*.

DESCRIPTION. Test medium-sized, inflated, coiled in a very low trochospire ; dorsal side depressed in the early part, inflated later ; ventral side more strongly inflated ; equatorial periphery quadrate and distinctly lobate ; axial periphery rounded ; chambers, 12, arranged in 2½ dextrally coiled whorls ; the initial ones are small, slightly inflated ; the last whorl is composed of 4½ large, globular, inflated chambers which increase rapidly in size except for the last which is slightly smaller than the penultimate and is slightly compressed ; on the ventral side the chambers are 4½, large, globular and strongly inflated ; sutures on the dorsal side curved, depressed in the early part, almost straight, radial and depressed later ; on the ventral side the sutures are radial and strongly depressed ; umbilicus irregular in outline, relatively wide, deep and open ; aperture a narrow crescentic arch, interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface of early chambers finely cancellate, becoming smoother towards the last chamber.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·43 mm.
Minimum diameter = 0·26 mm.
Thickness = 0·25 mm.

MAIN VARIATION.

1. Chambers 10–12, arranged in 2–3 whorls, generally dextrally coiled, but sinistral forms also occur (of 108 specimens picked at random, 36 coiled sinistrally).
2. Chambers in the last whorl 4–5.

REMARKS. Bolli (1957*b*) moved this species from *Globigerina* to *Globorotalia* because of its interiomarginal, extraumbilical-umbilical aperture.

The species is distinguished by its quadrate appearance, generally small last chamber, radially depressed sutures, and by the rough surface of its early chambers.

Globorotalia quadrata (White) has quite often been confused with *Globigerina bulloides* d'Orbigny and with superficially similar Maestrichtian *Rugoglobigerina* and *Hedbergella* species (e.g. White 1928 ; Nakkady 1959). *G. quadrata* is somewhat similar to *G. pseudobulloides* (Plummer) from which it is distinguished by the quadrilateral arrangement of its chambers, its small last chamber, its centrally depressed dorsal side, the rough surface of its early chambers and its straight, radial depressed sutures on the dorsal side. Some of the forms described by Loeblich & Tappan (1957*a*, pl. 44, figs. 4, 5) as *G. pseudobulloides* (Plummer), are probably *G. quadrata* (White).

Globorotalia quadrata (White) is believed to have evolved from *G. pseudobulloides* (Plummer) into *G. irrorata* Loeblich & Tappan as suggested by their morphological features and stratigraphical distribution. However, it is not excluded that the present species has also evolved into *G. angulata angulata* (White) by flattening of the dorsal side and the development of the rough surface.

HYPOTYPE. P.45627.

HORIZON AND LOCALITY. Figured specimen, from sample No. 7 Gebel El-Kilabiya section.

STRATIGRAPHICAL RANGE. White (1928) in his original description of the species stated that it is rare in the middle and upper Mendez formation of Mexico becoming quite abundant at the very base of the Velasco and only slightly less so throughout the lower part of the Velasco. It is quite evident that he confused *Globorotalia quadrata* with similar quadrilateral *Rugoglobigerina* and/or *Hedbergella* species in the Maestrichtian rocks below. Nakkady (1959) apparently made the same mistake and thus recorded his *Globigerina quadrata* White as ranging throughout the Maestrichtian–Danian–Montian of the Kharga Oasis, Egypt. His Montian is now regarded as Lower Eocene.

Bolli (1957*b*) recorded *Globorotalia quadrata* (White) from the lower Lizard Springs formation of Trinidad, where it was found to range through the *G. uncinata* Zone to the *G. pseudomenardii* Zone.

In the Esna–Idfu region, *G. quadrata* (White) floods the Upper Danian part of the sections studied. It continues as an abundant to common form upwards in the section, fading out gradually towards the basal part of the Upper Paleocene *G. velascoensis* Zone where it dies out completely.

Globorotalia sibaîyaensis sp. nov.

(Pl. 23, figs. 6*a*–*c*)

Diagnosis. A *Globorotalia* with small, globular, elongate test, slightly compressed in early part and inflated later; heavily spinose surface ; narrow umbilicus ; radial depressed sutures and long narrow aperture.

Description. Test very small, globular, slightly compressed, coiled in a very low trochospire ; dorsal side almost flat in the early part, inflated later ; ventral side moderately inflated ; equatorial periphery roughly ovoid, distinctly lobate and heavily spinose ; axial periphery rounded ; chambers on the dorsal side 12, arranged in two dextrally coiled whorls ; the initial chambers are small, inflated, globigerine, and increase slowly in size ; the last whorl is composed of 5½ relatively large, roughly globular chambers which increase gradually in size ; on the ventral side the chambers are 5½, relatively large, subglobular, slightly inflated in the early part, more strongly so later ; sutures on the dorsal side very slightly curved, depressed : on the ventral side they are striaght, radial and strongly incised ; umbilicus small, shallow and open aperture interiomarginal, extraumbilical-umbilical, a narrow, long slit extending from the umbilicus to the periphery ; wall calcareous perforate ; surface spinose and nodose.

Dimensions of holotype.

Maximum diameter = 0·29 mm.
Minimum diameter = 0·19 mm.
Thickness = 0·17 mm. (of last chamber)

Remarks. *Globorotalia sibaîyaensis* sp.nov. is distinguished from *G. perclara* Loeblich & Tappan, from which it is believed to have evolved, by its smaller test, entirely and heavily spinose surface, much narrower umbilicus and long slit-like aperture. It is distinguished from *G. uncinata uncinata* Bolli by its smaller size, globular form, heavily spinose surface and radial incised intercameral sutures. *Globorotalia intermedia* (Subbotina) differs from the present species in being more robust, more inflated on the ventral side and almost flattened on the dorsal, and in having fewer chambers which increase rapidly in size, and are strongly protruding on the ventral side, with closely adjacent umbilical ends. *Globorotalia sibaîyaensis* also appears to be morphologically similar to the holotype of the much younger *G. rugosoaculeata* (Subbotina) which is distinguished by its raised initial part.

Holotype. P.45628.

Paratype. P.45629.

Horizon and locality. Holo- and paratypes, from sample No. 50, Gebel Owaina section.

Stratigraphical range. The species occurs as a rare to common form in the *G. aequa*–*G. esnaensis* Subzone of uppermost Paleocene age.

Globorotalia tribulosa Loeblich & Tappan

(Pl. 18, figs. 2*a–c*)

1957*a* *Globorotalia tribulosa* Leoblich & Tappan : 195, pl. 56, figs. 3*a–c* ; pl. 61, figs. 7*a–c*.

Description. Test medium-sized, globular, inflated, coiled in a very low trochospire ; dorsal side flat in the early part, inflated later ; ventral side strongly inflated ; equatorial periphery roughly quadrate and distinctly lobate ; axial periphery rounded ; chambers on the dorsal side about 12–14, arranged in 2½ dextrally coiled whorls ; initial chambers very small, much flattened and almost masked by the surface rugosity ; the last whorl is composed of 4 large globular chambers which increase so rapidly in size that the last two chambers constitute most of the test ; on the ventral side the 4 chambers are also strongly inflated ; sutures on the dorsal side curved, depressed in the early part, almost straight, radial and depressed later ; on the ventral side they are radial and strongly incised ; umbilicus small, deep and open ; aperture a large, crescentic arch, interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface distinctly papillose, with the papillae sometimes tapering out to form fine, delicate spines giving the surface a hispid appearance.

Dimensions of described specimen.

Maximum diameter = 0·40 mm.
Minimum diameter = 0·22 mm.
Thickness = 0·24 mm.

Remarks. *Globorotalia tribulosa* is distinguished from *G. pseudobulloides* (Plummer), from which it probably evolved, by its rough, papillose and hispid surface. It differs from *G. esnaensis* (Le Roy) in having a more globular, lobate test, chambers which increase more rapidly in size, a characteristic large aperture and by the fact that its surface is not as rough as that of *G. esnaensis*. *G. tribulosa* appears to be transitional between *G. pseudobulloides* and *G. esnaensis*.

Hypotype. P.45630.

Horizon and locality. Figured specimen from sample No. 32, Gebel Owaina section.

Stratigraphical range. Loeblich & Tappan (1957*a*) described *G. tribulosa* from the Nanafalia formation of Alabama and the Aquia formation of Virginia which they considered as lower Eocene (Ypresian) and Upper Paleocene (Landenian) respectively. However, both Bramlette & Sullivan (1961) and Gartner & Hay (1962) considered the Nanafalia formation to be of Upper Paleocene age.

In the Esna–Idfu region *G. tribulosa* appears in the uppermost part of the Danian and continues as a common form throughout the overlying Middle Paleocene. It dies out completely in the basal part of the uppermost Paleocene, *G. aequa*/*G. esnaensis* Subzone.

Globorotalia trinidadensis Bolli

(Pl. 18, figs. 7*a–c*)

1957*b* *Globorotalia trinidadensis* Bolli : 73, pl. 16, figs. 19–23.
1960*b* *Globorotalia trinidadensis* Bolli : Bolli & Cita : 29–30, pl. 33, figs. 1*a–c*.

Description. Test large, globigerine, coiled in a low trochospire ; dorsal side nearly flat in the early part, strongly inflated in the last whorl ; ventral side strongly inflated ; equatorial periphery subcircular to ovoid, distinctly lobate ; axial periphery rounded ; chambers on the dorsal side 18, arranged in 3 dextrally-coiled whorls ; the initial ones are very small and slightly inflated ; the last whorl is composed of 6 large globular, strongly inflated chambers ; on the ventral side the chambers are 6, large, subglobular and strongly inflated, especially the penultimate one, which is slightly shifted towards the umbilicus ; sutures on the dorsal side slightly curved and depressed in the early part, nearly straight, radial, strongly depressed in the last whorl ; on the ventral side the sutures are nearly straight, radial and strongly depressed ; umbilicus irregular in outline, moderately wide, relatively deep, open ; aperture interiomarginal extraumbilical-umbilical, a narrow crescentic arch with a very thin lip-like flap ; wall calcareous, perforate ; surface slightly papillose in the early part, becoming smoother towards the last chamber.

Dimensions of described specimen.

Maximum diameter	=	0·50 mm.
Minimum diameter	=	0·36 mm.
Thickness	=	0·35 mm.

Main variation.

1. Chambers 14–18 arranged in 2–3 whorls generally dextrally coiled (of 175 specimens picked at random, 67 coiled sinistrally).
2. Chambers on the last whorl 6–7.

Remarks. *Globorotalia trinidadensis* Bolli is distinguihsed from *G. pseudobulloides* (Plummer) by its larger size, more numerous chambers in the final whorl, slightly rugose surface of the early chambers and by its last chamber which is often slightly smaller than the penultimate and is slightly compressed. It is believed to have evolved from *G. pseudobulloides* (Plummer) and to have given rise to *G. uncinata uncinata* Bolli. This is supported by their stratigraphical ranges and by the discovery in the present study of several transitional stages.

Hyptotypes. P.45631–32.

Horizon and locality. Figured specimen, from sample No. 7 Gebel El-Kilabiya section.

Stratigraphical range. The species was first described from the lower part of the Paleocene "Lower Lizard Springs formation of Trinidad", where it characterizes the *Globorotalia trinidadensis* Zone, and continues through the lower part of the overlying *Globorotalia uncinata* Zone. Bolli (1957*b*) did not relate his faunal zones to the European divisions of the Paleocene.

Globorotalia trinidadensis was also recorded from the Danian of the Paderno d'Adda section of northern Italy (Bolli & Cita 1960*a*, *b*), from the Danian of the Tampico Embayment of Mexico (Hay 1960) and from the Lower Paleocene of the Gubbio section, Italy (Luterbacher & Premoli Silva 1962).

In the Esna–Idfu region, *G. trinidadensis* floods the Danian in the sections studied and continues in the lower part of the Middle Paleocene *G. angulata* Zone where it dies out completely.

Globorotalia troelseni Loeblich & Tappan

(Pl. 17, figs. 10*a–c*)

1957*a* *Globorotalia troelseni* Loeblich & Tappan : 196, pl. 60, figs. 4*a–c* ; pl. 63, figs. 5*a–c*.

Description. Test medium sized, weakly biconvex, compressed, coiled in a very low trochospire ; dorsal side weakly inflated, with the initial chambers slightly depressed ; ventral side slightly inflated with a depressed umbilicus at its centre within which a portion of the earlier whorl is visible ; equatorial periphery roughly ovoid, distinctly elongate, and moderately lobate ; axial periphery subacute with a weakly develpoed marginal keel on the last chamber ; chambers on the dorsal side 11, arranged in 2 dextrally coiled whorls ; the initial ones are small, very weakly inflated, roughly globigerine and slightly depressed ; the last whorl is composed of 6½ chambers which are slightly compressed, globular in the early part, roughly lenticular, irregular, compressed later, and which increase so rapidly in size that the last chamber constitutes more than one third of the test ; on the ventral side, 8 chambers are visible ; they are globular, slightly compressed in the early part, roughly lenticular, compressed later and increase rapidly in size ; the extra 1½ are seen within the umbilical depression due to the tendency towards evolute coiling in the last whorl ; sutures on the dorsal side slightly curved, depressed ; on the ventral side they are very gently curved to almost straight, radial and depressed ; umbilicus very small, shallow ; aperture interiomarginal, extraumbilical-umbilical, a narrow arch extending to the periphery, with a small, delicate lip ; wall calcareous, perforate ; surface smooth with few, small, scattered papillae.

Dimensions of described specimen.

Maximum diameter	=	0·33 mm.
Minimum diameter	=	0·20 mm.
Thickness	=	0·12 mm.

Remarks. Loeblich & Tappan (1957*a*) stated that " This species is characterized by its tendency to become evolute, so that the early whorls are visible from both the spiral and umbilical sides." However, it is only the last 2 or 3 chambers of the early whorl that are visible within the umbilicus, not the whole of the whorl, otherwise it would not be considered a true *Globorotalia*.

Because of this tendency towards evolute coiling in the last whorl, *G. troelseni* may be considered as a link between *Globorotalia* and *Globanomalina* ; forms such as *Globanomalina eocenica* (Berggren) might possibly have evolved from *G. troelseni* in Lower Eocene time. On the other hand, *G. troelseni* is believed to have evolved from *G. emilei* sp. nov. in Upper Paleocene time by the development of a weak keel and the tendency towards evolute coiling in the last whorl.

The form figured as *G. troelseni* by Berggren (1960*c*) does not show the tendency towards evolute coiling which is the main characteristic of this species. It may belong to *G. emilei* sp.nov. or represent a transitional stage between it and *G. troelseni*. This is substantiated by the stratigraphical range assigned to this species by Berggren (1960*c*).

HYPOTYPE. P.45633.

HORIZON AND LOCALITY. Figured specimen, from sample No. 68, Gebel Owaina section.

STRATIGRAPHICAL RANGE. This species was described from the Nanafalia formation of Alabama and the upper part of the Velasco formation of Mexico, which Loeblich & Tappan (1957*a*) considered to be of Lower Eocene and Upper Landenian age respectively. However, the Nanafalia formation was considered to be of Upper Paleocene age on account of its nannoplankton (Bramlette & Sullivan 1961) and of its planktonic Foraminifera (Gartner & Hay 1962).

In the Esna–Idfu region *G. troelseni* appears as a rare form in the upper part of the Upper Paleocene *G. velascoensis* Zone. It crosses the Paleocene–Lower Eocene boundary and continues in the overlying *G. wilcoxensis* Zone.

Globorotalia uncinata carinata subsp. nov.

(Pl. 19, figs. 1*a–d*)

DIAGNOSIS. A *Globorotalia uncinata* with planoconvex test, thickened, nodose keel, imbricate dorsal side and rougher surface.

DESCRIPTION. Test medium-sized, almost planoconvex, coiled in a very low trochospire ; dorsal side flat, imbricate ; ventral side strongly protruding ; equatorial periphery ovoid, distinctly lobate ; axial periphery angular with a well-developed, very thick, heavily papillose or rather nodose keel ; chambers, as seen on dorsal side, 15, arranged in 2½ dextrally coiled whorls ; the inital ones are small, inflated and globigerine ; the last whorl is composed of 6, relatively large, almost crescentic, overlapping chambers, which increase slowly in size in the early part and rapidly later ; on the ventral side the chambers are 6, relatively large, strongly protruding, angular conical and increase rapidly in size towards the last chamber ; sutures on the dorsal side curved, depressed in the early part, strongly curved, depressed later, although they are marked by the thick, papillose, marginal keel as it curves on the dorsal side encircling the periphery of each chamber ; on the ventral side the sutures are almost straight, radial and strongly incised ; umbilicus small, deep and open ; aperture a low arch, interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface rough, heavily papillose, with the roughness decreasing gradually towards the last chamber ; the marginal keel is very thick, heavily papillose or even nodose.

DIMENSIONS OF HOLOTYPE.

Maximum diameter	=	0·37 mm.
Minimum diameter	=	0·24 mm.
Thickness	=	0·21 mm.

MAIN VARIATION.

1. Chambers 13–18, arranged in 2–3 tightly coiled whorls.
2. Coiling is random, with a tendency to be sinistral (of 29 specimens studied, 12 coiled sinistrally).
3. Chambers in the last whorl 5–6, rarely 7.

REMARKS. The tendency towards the development of a partial pseudo-keel was observed in specimens of *G. uncinata uncinata* Bolli from the Esna–Idfu region (e.g. Pl. 19, figs. 2*a–c*) and can be seen on the holotype of Bolli (1957*b*, pl. 17, figs. 13–15). This tendency was found to lead higher in the section to forms with very well-developed, thick, nodose keels, which are here described as *G. uncinata carinata*. This new subspecies is distinguished from *G. uncinata uncinata* Bolli, from which it is believed to have evolved, by its thick, nodose keel ; flat, imbricate dorsal side ; distinctly angular, axial periphery ; angular conical chambers on the ventral side, and rougher surface.

The marginal keel in *G. uncinata carinata* is very peculiar ; it is much thicker and rougher than any known keel in the genus *Globorotalia*. The well-developed rugosity does not allow one to see whether or not it is a true, imperforate keel, although it seems quite distinct from the rest of the test.

HOLOTYPE. P.45634.

PARATYPES. P.45635.

HORIZON AND LOCALITY. Holo- and paratypes, from sample No. 36, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The subspecies occurs as a rare form in the uppermost part of the Middle Paleocene, (the upper part of the *G. pusilla* Subzone), to which it seems to be restricted.

Globorotalia uncinata uncinata Bolli

(Pl. 18, figs. 1*a–c* ; Pl. 19, figs. 2*a–c*)

1957*b* *Globorotalia uncinata* Bolli : 74, pl. 17, figs. 13–15.
? 1960*b* *Globorotalia uncinata* Bolli ; Bolli & Cita : 30–31, pl. 32, figs. 5*a–c*, 7*a–c*.

DESCRIPTION. (Described specimen, Pl. 18, figs 1*a–c*.) Test small, almost planoconvex, coiled in a very low trochospire ; dorsal side nearly flat, ventral side strongly convex ; equatorial periphery subcircular to ovoid, distinctly lobate ; axial periphery subrounded ; chambers on the dorsal side about 12–15, arranged in 2–2½ sinistrally coiled whorls ; the initial chambers are small, indistinct, and are followed by crescentic, very slightly inflated chambers ; the last whorl is composed of 6, crescentic to nearly subcircular, slightly overlapping chambers which increase rapidly in size ; on the ventral side the chambers are 6, subangular, roughly triangular to subrounded, inflated to strongly protruding with the inflation increasing gradually towards the last chamber ; sutures on the dorsal side strongly curved, depressed ; on the ventral side they are very gently curved to nearly straight, radial and strongly depressed ; umbilicus irregular in outline, roughly stellate, very narrow, moderately deep and open ; aperture a narrow crescentic arch, interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface covered with small scattered papillae in the early part, becoming smoother towards the last chamber.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·300 mm.
Minimum diameter = 0·200 mm.
Thickness = 0·180 mm.

MAIN VARIATION.

1. Chambers 12–15, arranged in 2–3 tightly coiled whorls.
2. Coiling fairly random, with a tendency to be sinistral (of 32 specimens studied, 20 coiled sinistrally).
3. Chambers in the last whorl 5–7 ; 6 is most common.

REMARKS. *Globorotalia uncinata* includes various forms which can be assigned to the following three groups.

(A) Forms with a small test, a flat to slightly inflated dorsal side, a subrounded to subangular axial periphery, and a delicately papillose surface (Pl. 18, figs. 1*a–c*). These are believed to have evolved from *G. pseudobulloides* (Plummer) or its descendant *G. trinidadensis* Bolli, in Upper Danian time. Transitional stages between these forms and typical *G. pseudobulloides* and/or *G. trinidadensis* were figured by Bolli (1957*b*, pl. 17, figs 16–18) and were observed in the present study. On the other hand these forms are believed to have evolved into *G. angulata angulata* (White) in early Middle Paleocene time. Transitional stages between this group and typical *G. angulata angulata* were figured by Bolli (1957*b*, pl. 17, figs. 10–12) and have also been observed by the present author.

(B) Forms with a relatively large test, a flat to slightly inflated dorsal side, a rounded to subrounded axial periphery, a distinctly nodose or even spinose surface, and a thick, partially developed pseudo-keel (Pl. 19, figs. 2*a–c*). These forms are believed to have evolved from group A. The holotype described by Bolli (1957, pl. 17, figs. 13–15) most probably belongs to this group ; it shows clearly the partially developed pseudo-keel, although Bolli did not mention it in his description.

Slightly higher in the section, members of this group were found to pass gradually into group C.

(C) Forms with a medium-sized test, a flat, moderately to distinctly imbricate dorsal side, a strongly protruding ventral side, an acute axial periphery, an entire, thick, nodose keel, and a very rough, papillose surface.

The first two groups, although differing in surface texture, were found to occur together and to have almost the same stratigraphical range. They probably represent the end members of one and the same species population of which Bolli's holotype is a central form. They are thus both grouped under *G. uncinata uncinata*

cus ; sutures on the dorsal side curved, raised and beaded in the early part, almost straight, radial, depressed and beaded in the later part ; on the ventral side the sutures are radial and strongly incised ; umbilicus large, deep, open and crowned with a thick, beaded, everted collar ; aperture interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface smooth except for the heavily beaded keel, dorsal sutures and umbilical collar.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·66 mm.
Minimum diameter = 0·51 mm.
Thickness = 0·28 mm.

REMARKS. *Globorotalia velascoensis caucasica* was first described by Glaessner (1937*a*) as a variety of *G. aragonensis* Nuttall. Glaessner included in the synonymy of his new variety the form previously described by Subbotina (1936*a*) as *Globorotalia velascoensis* (Cushman) var. *aragonensis* Nuttall which was later reconsidered by Subbotina (1953) as *G. velascoensis* (Cushman).

Grimsdale (1951 : 471), Subbotina (1953 : 217–218) and Berggren (1960*d* : 110–111) considered Glaessner's variety to fall well within the range of variation of *G. velascoensis* (Cushman). On the other hand, Reiss (1957) followed Glaessner in considering this form as a variety of *G. aragonensis*, which he regarded as a *Truncorotalia*. However, the present study showed that Glaessner's variety is more closely related to *G. velascoensis* than to *G. aragonensis*, and that its morphological features and stratigraphical distribution warrant its separation as a distinct subspecies. It is distinguished from *G. velascoensis velascoensis* (Cushman) by its much larger test ; wider umbilicus ; circular, distinctly lobate equatorial periphery ; much thickened, heavily beaded, broader keel ; and by the roughly trapezoidal shape of its last chambers on the dorsal side.

The form figured by Hamilton (1953, p . 30, figs. 16–18) as *G. velascoensis* (Cushman) may belong to the present subspecies, but that figured by Sjutskaya (1956) as *G. aragonensis* var. *caucasica* is different from the holotype and from the form here figured.

Globorotalia velascoensis caucasica probably evolved from *G. velascoensis velascoensis* (Cushman) as it appears slightly later in the section. However, the evolutionary history of this subspecies could not be easily followed because of its rare occurrence in the samples studied.

HYPOTYPE. P.45638.

HORIZON AND LOCALITY. Figured specimen, from sample No. 41, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *G. velascoensis caucasica* was recorded by Glaessner (1937*a*) from what he described as the Lower Eocene of northwestern Caucasus. It was also recorded by Sjutskaya (1956) as occurring in what she described as Middle Eocene (Lutetian) of the central Sub-Caucasus, although her figures are different from those of Glaessner. However, analysis of recent Soviet work by Berggren (1960*d*) led him to conclude that " . . . the strata in which they occur cannot be considered to belong to the Middle Eocene (Lutetian) because of the absence of such typically developed forms as *Hantkenina*, *Truncorotaloides* and *Globigerapsis*, among others ". He also stated that the species population recorded from these strata are indicative of an Upper Paleocene–lowermost Eocene age as recognized elsewhere. On the other hand, Reiss (1957) argued for a Lower-Middle Eocene age for the present subspecies, but as he gave neither figure nor description, it is impossible to know what he meant by *Truncorotalia aragonensis caucasica*.

In the Esna–Idfu region, *G. velascoensis caucasia* occurs as a rare form in the lower part of the Upper Paleocene *G. velascoensis* Zone, the *G. pseudomenardii* Subzone.

Globorotalia velascoensis parva Rey

(Pl. 20, figs. 4*a–d*)

1953 *Globorotalia velascoensis* (Cushman) ; Hamilton (*pars*) : 231, pl. 31, figs. 24, 28, 29, non figs. 30, 31 non pl. 30, figs. 16–18.
1955 *Globorotalia velascoensis* (Cushman) var. *parva* Rey : 209, pl. 12, figs. 1*a–b*.
1960*b* *Globorotalia velascoensis parva* Rey ; Bolli & Cita : 32–33, pl. 33, figs. 5*a–c*.
? 1961 *Globorotalia* (*Truncorotalia*) *acuta* Toulmin ; Küpper : 257, pl. 16, figs. 3*a–c*.
? 1963 *Globorotalia acuta* Toulmin ; Aubert : 54–55, pl. 1, figs. 3*a–c*.

DESCRIPTION. Test large, planoconvex, umbilico-convex, coiled in a very low trochospire ; dorsal side flat ; ventral side distinctly protruding with a high umbilical shoulder and thick, beaded umbilical flange or collar ; equatorial periphery ovoid, distinctly lobate with a well-developed, broad, thick, heavily beaded marginal keel ; axial periphery strongly acute ; chambers on the dorsal side 9, arranged in 2 dextrally coiled whorls, increasing slowly in size in the early part and very rapidly later ; thus the last whorl constitutes most of the test and the last chamber about one-third of it ; the initial chambers are small, indistinct and very weakly raised ; the last whorl is composed of 4 large, typically crescentic chambers ; on the ventral side the chambers are 4, large, angular conical and strongly protruding, with their distal ends much thickened, beaded and surrounding the umbilicus in the form of an umbilical flange or collar ; sutures on the dorsal side curved, raised, much thickened and heavily beaded ; on the ventral side they are radial and strongly depressed ; umbilicus small, very deep, open and crowned with a thick, beaded collar ; aperture a narrow, long arch, interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface generally smooth with a few scattered papillae, except for the keel, dorsal sutures and umbilical collar, which are heavily papillose.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·60 mm.
Minimum diameter = 0·48 mm.
Thickness = 0·30 mm.

REMARKS. *Globorotalia velascoensis parva* was first described by Rey (1955) as a variety of *G. velascoensis* (Cushman). Gartner & Hay (1962) raised this variety to subspecific rank, a step which is strongly supported by this study, although their figures are different from the holotype of Rey and from the present hypotypes.

G. velascoensis parva differs from *G. velascoensis velascoensis* in having fewer chambers per test (7–9½), and fewer chambers in the last whorl (3½–4½) ; these are typically crescentic, much larger and increase much more rapidly in size as added. It is also distinguished by its slightly narrower umbilicus and distinctly lobate periphery.

Rey's holotype is not clearly figured, lacks the side view, and is incompletely described. However, he stated that the variety only differs from the central type in that the number of chambers is reduced to 3, 4 or 5 in the last whorl. This confirms its identity with the present subspecies, although forms with 5 chambers are here considered to belong to the central type.

Bolli & Cita (1960*b*) studied paratypes of *G. velascoensis parva* from Morocco and hypotypes from northern Italy, and their figured form conforms well with the specimens here studied.

Küpper (1961) described as *G.* (*T.*) *acuta* Toulmin, a form which appears to be *G. velascoensis parva* Rey.

Aubert (1963) described as *G. velascoensis* var. *parva* from the Paleocene of Morocco, a form which most probably belongs to *G. occlusa* Loeblich & Tappan. However, he confused the latter species with superficially similar forms and thus extended its range to the Lower Lutetian. On the other hand, he described as *G. acuta* Toulmin, which he restricted to the Paleocene only, a form which most probably belongs to the present subspecies.

Globorotalia velascoensis parva was lumped in the past with *G. velascoensis velascoensis* (Cushman) although their morphological features and stratigraphical distribution warrant their separation. Hamilton (1953), for example, figured under *G. velascoensis* (Cushman), forms which represent the central type and also its two subspecies (see synonymy).

G. velascoensis parva Rey is believed to have evolved from *G. velascoensis velascoensis* (Cushman) as suggested by their morphological features and stratigraphical ranges.

HYPOTYPE. P.45639.

HORIZON AND LOCALITY. Figured specimen, from sample No. 41, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The subspecies was first described by Rey (1955) from the Paleocene of Morocco, and was recorded (as *G. acuta*) from the Paleocene of the same country by Aubert (1963), who wrongly extended its range to the Lower Lutetian. It was also recorded from the Mid-Pacific seamounts (Hamilton 1953), the Paleocene of Italy (Bolli & Cita 1960*a*, *b* ; Luterbacher & Premoli Silva 1962 ; and Premoli Silva & Palmieri 1962), and from the Paleocene of Vienna Basin (Küpper 1961).

In the Esna–Idfu region *G. velascoensis parva* appears in the lower part of the Upper Paleocene *G. velascoensis* Zone, shortly after the first appearance of *G. velascoensis velascoensis*. It floods this zone together with the central type, but fades out gradually upwards in the section dying out completely in the *G. aequa*–*G. esnaensis* Subzone.

Globorotalia velascoensis velascoensis (Cushman)
(Pl. 20, figs. 3*a–d* ; Pl. 21, fig. 3)

1925 *Pulvinulina velascoensis* Cushman : 19, pl. 3, figs. 5*a–c*.
1926*b* *Pulvinulina velascoensis* Cushman ; Cushman : 608, pl. 21, fig. 9.
1927*a* *Globorotalia velascoensis* (Cushman) Cushman (pars) : 169, pl. 27, fig. 8, ? fig. 7, non fig. 9.
1928*b* *Globorotalia velascoensis* (Cushman) ; White : 281, pl. 38, figs. 2*a–c*.
1932 *Globorotalia velascoensis* (Cushman) ; Cushman & Jarvis : 51, pl. 15, figs. 8*a–c*.
1939*c* *Globorotalia crater* Finlay ; Finlay : 29, figs. 157, 162, 163.
1946 *Globorotalia velascoensis* (Cushman) ; Cushman : 153, pl. 63, fig. 6.
1946 *Globorotalia velascoensis* (Cushman) ; Cushman & Renz : 47, pl. 8, figs. 11, 12.
1947 *Globorotalia velascoensis* (Cushman) ; Subbotina : 123–127, pl. 7, figs. 9–11 ; pl. 9, figs. 21–23.
1949 *Globorotalia* (*Truncorotalia*) *velascoensis* (Cushman) ; Cushman & Bermudez : 41–42, pl. 8, figs. 4–6.
1951 *Globorotalia velascoensis* (Cushman) ; Nakkady (pars) : 54–55, pl. 1, fig. 6.
1953 *Globorotalia velascoensis* (Cushman) ; Hamilton (*pars*) ; 231, pl. 30, figs. 16–18, (non fig. 23), pl. 31, fig. 24, ? fig. 30 (non figs. 28, 29, 31).
1953 *Globorotalia velascoensis* (Cushman) ; Subbotina (pars) : 216–219, pl. 19, figs. 1*a*–2*c*, ? figs. 3*a*–4*c*.
1955 *Truncorotalia velascoensis* (Cushman) Dalbiez & Glintzboeckel (*in* Cuvillier *et al.*) : 533, pl. 2, figs. 8*a–c*.
1956 *Globorotalia velascoensis* (Cushman) ; Haque : 181–182, pl. 24, figs. 2*a*, *b*.
1957*b* *Globorotalia velascoensis* (Cushman) ; Bolli : 76–77, pl. 20, figs. 1–3, ? fig. 4.
1957*a* *Globorotalia velascoensis* (Cushman) ; Loeblich & Tappan : 196–197, pl. 64, figs. 1*a*–2*c*.
1957 *Globorotalia velascoensis* (Cushman) ; Sacal & Debourle : 64, pl. 29, figs. 7–9.
1958 *Globorotalia crater* Finlay ; Hornibrook : 33, pl. 1, figs. 3–5.
1959 *Globorotalia velascoensis* (Cushman) ; Hamilton & Rex : 794, pl. 252, figs. 18–20.
1960 *Globorotalia velascoensis* (Cushman) ; Bolli & Cita : 31–32, pl. 33, figs. 7*a–c*.
1961 *Globorotalia velascoensis* (Cushman) ; Said & Kerdany : 330, pl. 1, figs. 10*a–c*.
? 1962 *Globorotalia* (*Truncorotalia*) *velascoensis velascoensis* (Cushman) ; Hillebrandt : 139, pl. 13, ? figs. 16, 17 ; non figs. 18–21.
1963 *Globorotalia velascoensis* (Cushman) ; Aubert (pars) : 53–54, pl. 1, figs. 1*a–c*.

DESCRIPTION. (Described specimen Pl. 20, figs 3*a–d*). Test large, planoconvex, umbilico-convex, coiled in a very low trochospire ; dorsal side flat, ventral side strongly protruding ; equatorial periphery subcircular, lobate, with a distinct, broad, delicately beaded keel ; axial periphery angular, distinctly acute ; chambers on the dorsal side 16, arranged in 2½ sinistrally coiled whorls ; the initial ones are small, globigerine, compressed and are followed by typically crescentic chambers which increase slowly in size ; the last whorl is composed of 6 large, nearly crescentic to roughly quadrangular chambers which increase moderately in size ; on the ventral side the chambers are 6, large, angular conical and strongly protruding, with a papillose everted collar decorating their distal ends and surrounding the umbilicus ; sutures on the dorsal side curved, slightly raised and delicately beaded ; on the ventral side they are straight, radial and strongly depressed ; umbilicus roughly hexagonal in outline, wide, deep, open and surrounded by a thick beaded, everted collar, aperture a low arch, interiomarginal, extraumbilical-umbilical, with a narrow, delicate lip ; wall calcareous, finely perforate ; surface smooth, except for the keel, dorsal sutures and umbilical collar, which are distinctly papillose.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter	=	0·53 mm.
Minimum diameter	=	0·42 mm.
Thickness	=	0·26 mm.

MAIN VARIATION.

1. Chambers 12–18, arranged in 2½–3 whorls, generally sinistrally coiled (of 750 specimens picked at random, 56 coiled dextrally).
2. The last whorl is composed of 5–9 chambers, but 6–7 is most common.

REMARKS. *Globorotalia velascoensis velascoensis* was first described by Cushman (1925) as *Pulvinula velascoensis* n.sp. from the Velasco formation of Mexico. Cushman (1927) erected *Globorotalia* as a new genus in which he included *Pulvinulina velascoensis*. Cushman & Bermudez (1949) split the genus *Globorotalia* into three subgenera, and considered *G. velascoensis* to belong to the subgenus *Truncorotalia*. Dalbiez & Glintzboeckel (in Cuvillier *et. al.*, 1955) followed by Said & Kenway (1956) raised *Truncorotalia* to generic rank, without giving any reason, and considered *G. velascoensis* to be a *Truncorotalia*. Bermudez (1961) considered this species to belong to *Pseudogloborotalia* Haque, which is a poorly defined genus and may be, in part, a junior synonym of *Globorotalia* Cushman. Hillebrandt (1962) assigned *G. velascoensis* to the subgenus *Truncorotalia*, and included *G. occlusa* Loeblich & Tappan as a subspecies of it. However, as mentioned above, the subgeneric classification of the genus *Globorotalia* is best avoided as most forms grade imperceptibly into one another and no sharp lines of demarcation can be drawn. Again, although *G. occlusa* is morphologically rather similar to *G. velascoensis*, their differences are too great for them to be included in the same species.

The present study showed that *G. velascoensis* (Cushman) includes three distinct subspecies, namely :

Globorotalia velascoensis velascoensis (Cushman).
Globorotalia velascoensis caucasica Glaessner.
Globorotalia velascoensis parva Rey.

Subbotina (1936) considered *G. aragonensis* Nuttall to be a variety of *G. velascoensis*, and described as *G. velascoensis* (Cushman) var. *aragonensis* Nuttall, a form which she later (Subbotina 1953 : 217–218) reconsidered as *G. velascoensis* (Cushman). Glaessner (1937*a*) used Subbotina's form as a basis for a new variety which he named *G. aragonensis* Nuttall var. *caucasica*. However, this was found to be more closely related to *G. velascoensis* than to *G. aragonensis*, and is thus included here as a subspecies of the former, although both Grimsdale (1951) and Subbotina (1953) considered it to be synonymous with *Globorotalia velascoensis velascoensis*.

Finlay (1939*a*) described as *G. crater* n.sp. from the Heretaungan stage of New Zealand, a form which was described as " . . . like *aragonensis* . . . but has only four or five chambers per whorl, a sharp keel, and a practically flat top ", but no figure was given until later (Finlay 1939*c*). These later figures were described by Hornibrook (1958) as being of specimens from older beds and therefore not typical. However, the figures given by Hornibrook (pl. 1, figs. 3–5) as *G. crater* Finlay conform well with *G. velascoensis velascoensis* (Cushman) although the ventral side is more protruding. Variation in the degree of protrusion of the ventral side in *G. velascoensis velascoensis* is clearly documented in the present study (e.g. Pl. 21, fig. 3) and proves *G. crater* Finlay to be a junior synonym. Examination of topotypes of *G. crater* Finlay, kindly sent to the present author by Drs. N. de B. Hornibrook and G. Jenkins of the New Zealand Geological Survey, showed its identity with *G. velascoensis velascoensis* (Cushman) in spite of minor differences which fall well within the range of variation of the latter.

Haynes (1955, 1956) described as *Globorotalia velascoensis* (Cushman) aff. var. *acuta* (Toulmin), from the type Thanetian of England, a reworked Upper Cretaceous *Globotruncana* species. This record of Haynes was used by various authors (e.g. Loeblich & Tappan 1957*a*, *b* ; Bolli & Cita 1960*a*, *b* ; etc.) as a basis for considering the *G. velascoensis* Zone to be of Thanetian age. However, *Globorotalia velascoensis* (Cushman) was neither observed in the collection of Dr. Haynes, nor in the various type Thanetian samples, recently collected by the present author.

Bolli (1957*b*) included *G. acuta* Toulmin in the synonymy of *G. velascoensis* (Cushman), while Loeblich & Tappan (1957*a*) considered them separately.

Globorotalia velascoensis velascoensis (Cushman) is distinguished by its large, planoconvex, strongly umbilico-convex test ; its characteristic umbilical collar ; well-developed, beaded keel ; curved, raised, beaded, dorsal sutures and radial, incised ventral ones ; its smooth surface ; large, deep umbilicus and characteristic aperture. It is believed to have evolved from *G. angulata abundocamerata* Bolli into its two other subspecies as well as into *G. bollii* sp. nov. and *G. formosa gracilis* Bolli. This is substantiated by the morphological characters and stratigraphical distribution of these forms, and by the occurrence of several transitional stages.

HYPOTYPES. P.45640–41.

HORIZON AND LOCALITY. Figured specimens, Pl. 20, figs. 3*a–d*, from sample No. 41, and Pl. 21, fig. 3, from sample No. 37, Gebel Owaina section.

STRATIGRAPHICAL RANGE. *Globorotalia velascoensis velascoensis* (Cushman) is one of the finest known Upper Paleocene index fossils. It has been recorded from practically every part of the world where rocks of this age have been studied. It characterizes and is restricted to the *G. velascoensis* Zone (uppermost Paleocene), although some authors have wrongly extended its range to the Middle Eocene, and others have considered the zone to fall entirely within the Lower Eocene. The dispute over the stratigraphical position of the zone does not lessen the value of *G. velascoensis* in stratigraphical correlation, although misidentification of the species and confusion with other species has thrown some doubt on its true stratigraphical range. Nevertheless, all reliable records show that *G. velascoensis velascoensis* (Cushman) is restricted to the Upper Paleocene, and that records of this species from older or younger strata are erroneous.

In the Esna–Idfu region, *G. velascoensis velascoensis* floods the upper part of the Paleocene, constituting a distinct faunal zone, the *G. velascoensis* Zone. The first appearance of *G. velascoensis velascoensis* (Cushman) is used to mark the base of the Upper Paleocene, while its complete disappearance marks the dawn of the Eocene.

Globorotalia whitei Weiss

(Pl. 23, figs. 3*a–c*)

1928 *Globigerina crassaformis* Galloway & Wissler ; White : 193, pl. 27, figs. 14*a–c*.
1935 *Globorotalia crassaformis* (Galloway & Wissler) Nuttall : 130, pl. 15, figs. 21, 29.
1955*a* *Globorotalia whitei* Weiss : 18, pl. 6, figs. 1–3.
1955*b* *Globorotalia whitei* Weiss ; Weiss : 308, pl. 1, figs. 29, 30.
1957*b* *Globorotalia wilcoxensis* Cushman & Ponton ; Bolli : 79, pl. 19, figs. 7–9.
1959 *Globorotalia whitei* Weiss ; Hamilton & Rex : 794, pl. 253, figs. 1, 2.

DESCRIPTION. Test medium-sized, planoconvex, strongly umbilico-convex, coiled in a very low trochospire ; dorsal side very weakly inflated or almost flat ; ventral side strongly inflated and distinctly protruding ; equatorial periphery roughly ovoid, distinctly lobate ; axial periphery bluntly angular ; chambers on the dorsal side about 9 in number, arranged in 2 dextrally coiled whorls ; the initial chambers are small, globular, compressed, and almost masked by the surface rugosity ; the last whorl is composed of 4, large, roughly ovoid chambers which increase rapidly in size, and are elongated in the direction of coiling ; on the ventral side the chambers are 4, large, subglobular in the early part and roughly ovoid later, strongly inflated and increase rapidly in size ; sutures on the dorsal side, short, slightly curved and depressed ; on the ventral side they are long, straight, radial and strongly incised ; umbilicus small, deep and open with the ventral sutures radiating from it in an X-shaped pattern ; aperture interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface distinctly papillose or even nodose, with the nodes sometimes tapering out to form stout, spine-like projections, especially along the periphery.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter = 0·38 mm.
Minimum diameter = 0·30 mm.
Thickness = 0·26 mm.

REMARKS. *Globorotalia whitei* was described by White (1928) and Nuttall (1935) as *Globigerina crassaformis* Galloway & Wissler and as *Globorotalia crassaformis* (Galloway & Wissler) respectively. However, *G. crassaformis* is a Pleistocene form which is completely different from the present species.

Bolli (1957*b*) described as *G. whitei* Weiss, from the lower Lizard Springs formation of Trinidad, forms which are different from the original description and figures of Weiss. On the other hand, he described as *G. wilcoxensis* Cushman & Ponton a form which most probably belongs to *G. whitei*.

Globorotalia whitei is distinguished by its medium-sized, umbilico-convex test ; its small number of chambers per test and in the last whorl, subangular axial periphery, narrow umbilicus, X-shaped ventral sutures and very rough surface. It is believed to have evolved from *Globorotalia esnaensis* (Le Roy) by the flattening of the dorsal side, the development of the subangular axial periphery, and the change of the surface spines into stout knobs. It is also believed to have evolved into

G. wilcoxensis Cushman & Ponton by the development of the sharply acute axial periphery of the last chamber, and by the increase in surface rugosity.

Hypotype. P.45642.

Horizon and locality. Figured specimen, from sample No. 55, Gebel Owaina section.

Stratigraphical range. The species was described by Weiss (1955*a*, *b*) from the Paleocene and Lower Eocene of northwestern Peru. It was previously recorded by White (1928) from the Tampico Embayment of Mexico, where he described its range as being Upper Cretaceous–Paleocene. He certainly confused it with superficially similar *Globotruncana* or *Hedbergella* species in the Upper Cretaceous rocks below, and thus obscured its range. *G. whitei* was also recorded from the Lower Eocene of Venezuela (Nuttall 1935), the Lower Eocene *Globorotalia rex* Zone of the upper Lizard Springs formation of Trinidad (Bolli 1957*b*) and from the lowermost Eocene of the Sylvania guyot, Mid-Pacific (Hamilton & Rex 1959).

In the Esna–Idfu region *G. whitei* occurs as a common to abundant form in the uppermost Paleocene *G. aequa–G. esnaensis* Subzone. It crosses the Paleocene–Lower Eocene boundary and dies out in the overlying *G. wilcoxensis* Zone.

Globorotalia wilcoxensis Cushman & Ponton

(Pl. 23, figs. 5*a–c*)

1932 *Globorotalia wilcoxensis* Cushman & Ponton : 71, pl. 9, figs. 10*a–c*.
1939 *Globorotalia wilcoxensis* Cushman & Ponton ; Cushman & Garrett : 88, pl. 15, figs. 21, 22.
1944 *Globorotalia wilcoxensis* Cushman & Ponton ; Cushman : 15, pl. 2, figs. 14, 15.
1948 *Globorotalia wilcoxensis* Cushman & Ponton ; Cushman & Todd : 36, pl. 6, figs. 24, 25.
1948 *Globorotalia wilcoxensis* Cushman & Ponton ; Shifflett : 73, pl. 40, figs. 20–22.
1949 *Globorotalia* (*Truncorotalia*) *wilcoxensis* Cushman & Ponton ; Cushman & Bermudez : 39, pl. 7, figs. 16–18.
1953 *Globorotalia wilcoxensis* Cushman & Ponton ; Hamilton : 231, pl. 32, fig. 7.
1955*a* *Globorotalia wilcoxensis* Cushman & Ponton ; Weiss : 19, pl. 6, figs. 7–9.
1955*b* *Globorotalia wilcoxensis* Cushman & Ponton ; Weiss : 308, pl. 1, figs. 24, 25.
1958 *Globorotalia wilcoxensis* Cushman & Ponton ; Asano : 46, pl. 12, figs. 4*a–c*.

Description. Test medium-sized, planoconvex, coiled in a very low trochospire ; dorsal side flat, slightly compressed, ventral side inflated, protruding ; equatorial periphery roughly ovoid, distinctly lobate ; axial periphery subrounded to subangular in the early part, angular in the later part ; chambers on the dorsal side about 9, arranged in 2 dextrally coiled whorls ; the initial chambers are small, almost masked by the surface rugosity and are followed by large, crescentic, overlapping chambers which increase moderately in size ; the last whorl is composed of 4, large, roughly ovoid chambers, which are elongated in the direction of coiling, and increase slowly and regularly in size, except for the last which is slightly smaller than the penultimate ; on the ventral side the chambers are 4, large, subglobular and strongly inflated ; sutures on the dorsal side curved, depressed ; on the ventral side they are straight, radial and strongly incised ; umbilicus small, deep and open (although in the figured specimen the last chamber is strongly pushed over the umbilicus) ; aperture interiomarginal, extraumbilical-umbilical ; wall calcareous, perforate ; surface distinctly papillose or even nodose with the nodes tapering out sometimes to form stout, spine-like projections, especially along the periphery.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter	=	0·41 mm.
Minimum diameter	=	0·28 mm.
Thickness	=	0·20 mm.

REMARKS. *Globorotalia wilcoxensis* is distinguished by its medium-sized, plano-convex, roughly ovoid, distinctly lobate test ; its axial periphery which is subrounded in the early part, angular in the last chamber ; its curved depressed spiral suture ; its curved, depressed, dorsal intercameral sutures, which are radial and strongly incised on the ventral side, and its heavily nodose or even spinose surface.

The species is believed to have evolved from *G. whitei* Weiss in uppermost Paleocene time by the slight increase in the size of test, the close coiling of the early chambers which become crescentic rather than globular, and by the development of the more acute axial periphery of last chamber. On the other hand, it has possibly evolved into *G. quetra* Bolli by the increase in the size of test, compression of the dorsal side, and the development of the acute axial periphery and the partially developed spinose keel.

Subbotina (1953) included *G. wilcoxensis* in the synonymy of *G. crassata* (Cushman) in spite of their marked difference. However, her *G. crassata* actually belongs to *G. aequa* Cushman & Renz which is also quite distinct from the present species.

Said & Kenawy (1956) described as *Truncorotalia wilcoxensis* (Cushman & Ponton) from the Paleocene of Nekhl section, northern Sinai, Egypt, a form which has nothing in common with *G. wilcoxensis* but most probably belongs to *G. aragonensis* Nuttall, thus proving their Paleocene to be of Lower Eocene age.

Bolli (1957*b*) described as *G. wilcoxensis* Cushman & Ponton, a form which appears to be more closely related to *G. whitei* Weiss, while the form described by Hamilton & Rex (1959) cannot be assigned to any known species.

Berggren (1960*a*) described as *G. wilcoxensis* from the Lower Eocene of Denmark, forms which may be related to *G. esnaensis* (LeRoy).

HYPOTYPE. P.45643.

HORIZON AND LOCALITY. Figured specimen, from sample No. 64, Gebel Owaina section.

STRATIGRAPHICAL RANGE. Cushman & Ponton (1932) described *G. wilcoxensis* from the Lower Eocene Wilcox group of Alabama, and it was recorded from the same group by Cushman & Garrett (1939) and Cushman (1944). It was also recorded from the Lower Eocene Wilcox group of Virginia and Maryland (Cushman 1944*b* and Shifflett 1948) ; the Middle Eocene of the Mississippi (Cushman & Todd 1948) ; the Paleocene Madruga formation of Cuba (Cushman & Bermudez 1949) and the Lower and Upper Eocene of the same area (Bermudez 1950) ; from the Eocene of the Gulf of Mexico, the Carribbean region and the Middle East (Grimsdale 1951) ; from the Eocene of the mid-Pacific sea mounts (Hamilton 1953) and the Paleocene Salina and Pale Greda formations of Peru (Weiss 1955*a*, *b*).

In the Esna–Idfu region, *G. wilcoxensis* appears at the top of the *G. velascoensis* Zone as a rare form which crosses the Paleocene–Lower Eocene boundary, and increases gradually upwards in the section to flood the basal part of the Eocene, characterizing the *Globorotalia* wilcoxensis Zone.

Globorotalia woodi sp. nov.

(Pl. 23, figs. 2*a–c*)

Diagnosis. A *Globorotalia* with small, umbilico-convex test ; chambers which increase rapidly in size ; narrow umbilicus ; long, narrow aperture ; curved, depressed dorsal sutures and slightly curved, incised ventral ones ; delicate but distinct marginal keel ; delicately papillose surface.

Description. Test small, umbilico-convex, coiled in a low trochospire ; dorsal side almost flat, although the early chambers are slightly raised ; ventral side distinctly protruding ; equatorial periphery ovoid, elongate, slightly lobate with a delicately beaded marginal keel ; axial periphery angular, acute ; chambers on the dorsal side are not all clear because of the surface rugosity, but appear to be 11 in number, arranged in 2 sinistrally coiled whorls ; the last whorl is composed of 5 relatively large crescentic chambers, which increase rapidly in size ; on the ventral side, the chambers are 5, roughly triangular, angular conical, increasing rapidly in size ; sutures on the dorsal side curved, delicately beaded, and slightly depressed ; on the ventral side they are slightly curved and strongly depressed ; umbilicus extremely small, moderately deep and open ; aperture interiomarginal, extraumbilical-umbilical, a long, narrow arch, with a narrow delicate lip ; wall calcareous perforate ; surface rough papillose, with the roughness decreasing gradually towards the last chamber.

Dimensions of holotype.

Maximum diameter = 0·27 mm.
Minimum diameter = 0·21 mm.
Thickness = 0·15 mm.

Remarks. *Globorotalia woodi* sp. nov. is morphologically similar to both *Globorotalia planoconica* Subbotina and *Globorotalia pseudoscitula* var. *elongata* Glaessner. It differs from the former in having a slightly larger test, more protruding ventral side, slightly curved ventral sutures, well-developed marginal keel, and rough surface. It is distinguished from *G. pseudoscitula* var. *elongata* Glaessner by its well developed marginal keel, sharply angular axial periphery and rough surface.

Globorotalia woodi is believed to have evolved from *G. emilei* sp. nov. either directly or indirectly through its descendant *G. pseudomenardii* Bolli by flattening of the dorsal side and greater protrusion of the ventral, and by the development of a more tightly coiled test, rough surface and a delicately beaded keel.

This species is named after Professor Alan Wood, U.C.W., Aberystwyth.

Holotype. P.45616.

PARATYPE. P.45671.

HORIZON AND LOCALITY. Holo- and paratypes, from sample No. 40, Gebel Owaina section.

STRATIGRAPHICAL RANGE. The species occurs as a rare to common form throughout the Upper Paleocene *G. velascoensis* Zone, of the Esna–Idfu region.

Globorotalia sp.

(Pl. 23, figs. 8*a–d*)

DESCRIPTION. Test medium-sized, strongly umbilico-convex, coiled in a very low trochospire ; dorsal side slightly depressed, ventral side strongly protruding, equatorial periphery roughly quadrate, distinctly lobate, with a faint, delicately beaded marginal keel which is sometimes masked by the surface rugosity ; axial periphery, sharply angular, acute ; chambers on the dorsal side about 9, arranged in 2 sinistrally coiled whorls ; the initial chambers are small, indistinct and almost masked by the surface rugosity ; the last whorl is composed of $4\frac{1}{2}$ chambers ($3\frac{1}{2}$ + 1 broken) which are large, roughly oblong-shaped, elongate and increasing slowly in size ; on the ventral side the chambers are $4\frac{1}{2}$ ($3\frac{1}{2}$ + 1 broken), large, inflated, strongly protruding, and much longer than wide ; sutures on the dorsal side short, curved and depressed ; on the ventral side they are radial and strongly incised ; umbilicus very small, narrow and open ; aperture interiomarginal, extraumbilical-umbilical, a long, crescentic arch, extending almost to the periphery ; wall calcareous, perforate ; surface heavily papillose or even nodose, with the nodes sometimes tapering out to form stout spine-like projections.

DIMENSIONS OF DESCRIBED SPECIMEN.

Maximum diameter	=	0·39 mm.
Minimum diameter	=	0·34 mm.
Thickness	=	0·27 mm.

REMARKS. Although this form could not be assigned to any known species of *Globorotalia*, it was decided not to describe it as new pending further study.

It is distinguished by its medium-sized test ; quadrate appearance ; sharply angular axial periphery ; flat or slightly concave dorsal side and protruding ventral one ; oblong shaped chambers on the dorsal side, and triangular, elongated chambers on the ventral; curved, depressed dorsal sutures and radial incised ventral ones ; narrow umbilicus, weakly developed marginal keel, and rough surface.

The forms described by Loeblich & Tappan (1957*a*, pl. 46, figs. 7*a*–8*c* ; pl. 59, figs. 6*a–c*) as *G. aequa* Cushman & Renz are very similar.

MATERIAL. P.45644.

HORIZON AND LOCALITY. Figured specimen, from sample No. 35, Gebel Owaina section.

STRATIGRAPHICAL RANGE. This form is rare in the upper part of the Middle Paleocene *G. angulata* Zone. It crosses the Middle–Upper Paleocene boundary and continues in the lower part of the *G. velascoensis* Zone, the *G. pseudomenardii* Subzone where it dies out gradually towards the top.

VI. SUMMARY AND CONCLUSIONS

A detailed examination of the various outcrops in the Esna–Idfu region has led to the classification of its Upper Cretaceous–Lower Tertiary succession into five formations and eight members, three formations and seven members of which are here described for the first time. These are as follows :

TOP	E. The Thebes Limestone and Calcareous Shale Formation.	The Libya Group
	8. The Thebes Limestone Member.	
	7. The Thebes Calcareous Shale Member.	
	D. The Owaina Shale Formation.	The Esna Group
	6. The Upper Owaina Shale Member.	
	5. The Middle Owaina Chalk Member.	
	4. The Lower Owaina Shale Member.	
	DISCONFORMITY	
	C. The Sharawna Shale Formation.	
	3. The Upper Sharawna Shale Member.	
	2. The Middle Sharawna Marl Member.	
	1. The Lower Sharawna Shale Member.	
	B. The Sibaîya Phosphate Formation.	The Nubia Group
	A. The Nubia Sandstone and Variegated Shale Formation.	

These rock units were used as a basis for the detailed mapping of the region. This mapping has proved the existence of a distinct stratigraphical break between the Maestrichtian and the overlying Paleocene. In spite of repeated emphasis on the absolute conformity of the succession by previous authors, a conglomerate with reworked Upper Cretaceous fossils was clearly observed in the field and was found to mark a distinct faunal break in the succession. The detailed lithostratigraphy and the maps are presented elsewhere (El-Naggar, *in manu*), but small scale reproductions of these maps are, however, given here to show the distribution of the various rock units and the locations of the sections examined.

The succession was first zoned on the basis of its macrofossils. One hundred and forty two species were identified. Consideration of their ranges led to the recognition of five faunal zones and three subzones, in addition to a zone devoid of macrofossils near the top and a non-fossiliferous zone at the base of the succession. These are as follows :

TOP 7. The *Lucina thebaica* Zone.
6. A Zone devoid of macrofossils.
5. The *Ostrea hypoptera* Zone.
4. The *Caryosmilia granosa* Zone.
DISCONFORMITY
3. The *Pecten* (*Chlamys*) *mayereymari* Zone.
    (*c*) The *Libycoceras berisensis* Subzone.
    (*b*) The *Pecten* (*Chlamys*) *mayereymari* Subzone.
    (*a*) The *Terebratulina gracilis* Subzone.
2. The *Lopha villei* Zone.
1. A non-fossiliferous Zone.

This faunal sequence has been correlated with previously described successions elsewhere in Egypt.

The planktonic Foraminfera from eight main sections representing the succession in different parts of the region were then studied. One hundred and nineteen species and subspecies were identified, twenty species and six subspecies of which are new. These provided a sound basis for the zonation of the succession and for its correlation with the known planktonic foraminiferal zones in other parts of the world. This zonal scheme has helped to establish the true ranges of the co-existent macrofossils, most of which are not known from outside the Middle East and North Africa. Again, the rich planktonic foraminiferal populations encountered have helped to clear up the confusion surrounding most of the species and to establish their morphological characters and stratigraphical ranges. They have also helped to explain the inter- and intra- specific variations among large species populations and have indicated certain trends and tendencies in their phylogenetic development. Seven faunal zones and four subzones have been erected on the basis of the planktonic Foraminifera ; in addition, three other zones, which are either devoid of planktonic Foraminifera or which contain rare indeterminable forms have been recognized. These zones and subzones are as follows :

10. A Zone with indeterminable planktonic Foraminifera.
9. The *Globorotalia wilcoxensis* Zone.
8. The *Globorotalia velascoensis* Zone.
    (*b*) The *Globorotalia aequa*/*Globorotalia esnaensis* Subzone.
    (*a*) The *Globorotalia pseudomenardii* Subzone.
7. The *Globorotalia angulata* Zone.
    (*b*) The *Globorotalia pusilla* Subzone.
    (*a*) The *Globorotalia uncinata* Subzone.
6. The *Globorotalia compressa*/*Globigerina daubjergensis* Zone.

DISCONFORMITY

5. The *Globotruncana esnehensis* Zone.
4. The *Globotruncana gansseri* Zone.
3. The *Globotruncana fornicata* Zone.
2. A Zone with rare indeterminable planktonic Foraminifera.
1. A Non-fossiliferous Zone.

A consideration of the lithological classification of the succession together with the macro-fossil and planktonic foraminiferal zonation enabled a correlation to be made with comparable successions in Egypt and other parts of the world, and led to the following conclusions :

A. CONCLUSIONS CONCERNING THE STRATIGRAPHY OF THE ESNA–IDFU REGION.

1. The Nubia Sandstone and Variegated Shale, which is the oldest formation to crop out in the region is of Campanian and ?pre-Campanian age.

2. The Sibaîya Phosphate formation is of Upper Campanian age. It is characterized by the *Lopha villei* Zone and is equated with the *Bostrychoceras polyplocum* Zone which characterizes the Upper Campanian in its type section.

3. The Sharawna Shale formation is of Maestrichtian age. It conformably overlies the Sibaîya Phosphate formation, and is separated from the overlying Paleocene Owaina shale formation by a distinct break. It is characterized by one major macro-fossil zone, the *Pecten* (*Chlamys*) *mayereymari* Zone, which contains three subzones as mentioned above. It is divided on the basis of its lithology into three distinct members : the Lower Sharawna Shale member, the Middle Sharawna Marl member and the Upper Sharawna Shale member. These correspond to the *Terebratulina gracilis* Subzone, the *Pecten* (*Chlamys*) *mayereymari* Subzone and the *Libycoceras berisensis* Subzone in the macrofossil zonation respectively. They also correspond to the *Globotruncana fornicata* Zone, the lower part of the *Globotruncana gansseri* Zone and both the upper part of the latter zone and the *Globotruncana esnehensis* Zone in the planktonic foraminiferal zonation. These three planktonic foraminiferal zones are taken to represent the Lower, Middle and Upper Maestrichtian and are correlated with corresponding zones in other parts of the world.

4. The Mesozoic–Cainozoic boundary in the Esna–Idfu region is marked by a distinct break and by a well developed conglomerate as mentioned above. It has been shown that this break is widespread throughout the country and exists in regions where conformity has hitherto been assumed.

5. The disconformity which marks the top of the Maestrichtian Sharawna Shale formation indicates the passage of a relatively long period of time, and represents the uppermost Maestrichtian as well as the Lower and Middle Danian.

6. The Owaina Shale Formation is of Paleocene age. It disconformably overlies the Maestrichtian Sharawna Shale and includes three members : The Lower Owaina Shale member, the Middle Owaina Chalk member and the Upper Owaina Shale member. Its Lower and Middle members coincide with both the *Caryosmilia granosa* and the *Ostrea hypoptera* Zones respectively, while its upper member is devoid of macrofossils except for rare dwarfed forms seen only in washed residues. On the basis of its planktonic Foraminifera, the Owaina Shale formation is divided into the three zones and four subzones listed above. The *Globorotalia* compressa/*Globigerina daubjergensis* Zone which coincides with the basal part of the Lower Sharawna Shale member, is also known to characterize the Danian in its type section and in other parts of the world. However the abundance of *G. compressa* clearly indicates that this part of the succession corresponds to the Upper Danian only, and proves that both the Lower and Middle Danian are missing. The *G. compressa/G. daubjergensis* Zone represents the Lower Paleocene (or Danian), while the *G. angulata* and the *G. velascoensis* Zones represent the Middle and Upper Paleocene respectively.

7. The various stage and substage names of the Paleocene such as the Montian, Thanetian, Sparnacian, Landenian, Heersian, Seelandian, etc., could not be applied because the relationship between one stage and another is not clearly understood, and the proper position of each in Paleocene stratigraphy is not known.

8. The Maestrichtian Sharawna Shale and the Paleocene Owaina Shale formations, together constitute a major group, commonly known as the Esna Shale. Previous classifications of this group into lower and upper Esna Shale, or into Dakhla and Esna shales are incorrect.

9. The Paleocene–Eocene boundary is marked by the upper limit of the *Globorotalia velascoensis* Zone.

10. The Thebes Limestone and Calcareous Shale formation is of Lower Eocene age. It is naturally classified into : a lower, " Thebes Calcareous Shale member ", and an upper, " Thebes Limestone member ", which forms the top part of the succession in the region. The former member is devoid of macrofossils except for rare dwarfed forms seen only in washed residues. It is characterized by the *Globorotalia wilcoxensis* Zone which is taken to mark the basal Eocene in Egypt and in other parts of the world. The latter member corresponds to the *Lucina thebaica* Zone of the macrofossil zonation. It is flooded with larger Foraminifera such as *Nummulites*, *Operculina*, *Assilina*, *Discocyclina*, etc., but, because of its silicification, it has not yet yielded any determinable planktonic forms. Nevertheless, its lower part, most probably, still belongs to the *G. wilcoxensis* Zone.

B. GENERAL CONCLUSIONS.

1. The Maestrichtian is considered to be a distinct stage in Upper Cretaceous stratigraphy, younger than, and equal in rank to the Senonian stage, while the Campanian is considered to be the upper substage of the Senonian as previously suggested by Jeletzky 1951.

2. The Campanian–Maestrichtian boundary is drawn at the top of the *Bostrychoceras polyplocum* Zone = the *Lopha villei* Zone = the *Globotruncana calcarata* Zone which marks the top of the Campanian in different parts of the world.

3. The Maestrichtian is divided on the basis of its planktonic Foraminifera into three successive zones ; the *Globotruncana fornicata* Zone, the *Globotruncana gansseri* Zone and the *Globotruncana esnehensis* Zone. The lowest zone is younger than the Upper Senonian in its type sections, while the upper zone is correlated in part with the *Abathomphalus mayaroensis* Zone which marks the Upper Maestrichtian rocks below the type Danian. A study of the type Maestrichtian should reveal the existence of these zones in Holland.

4. The Danian is considered to be the oldest stage of the Tertiary system, and the Maestrichtian–Danian contact is taken to mark the Mesozoic–Cainozoic boundary.

5. Comparison with previously studied Upper Cretaceous–Lower Tertiary successions, showed that in Egypt, this succession which was previously held to be a classical example of continuous deposition between the Cretaceous and the Tertiary is marked by breaks of varying magnitude. Comparison with similar successions in other parts of the world showed that the Mesozoic is separated from the Cainozoic in all known sections by a world-wide break, the cause of which awaits explanation.

6. The Paleocene is considered to be a distinct series at the base of the Tertiary system. older than, and equal in rank to the Eocene series. It spans the time between the top of the Cretaceous and the base of the Eocene, and includes the Danian as its lowest stage. The controversy over the chronological and stratgraphical relationships of the various other stages and substages of the Paleocene (e.g. the Montian, Thanetian, Sparnacian, Landenian, Heersian, Seelandian, etc.), necessitates the temporary abandonment of these terms, and the use of planktonic

foraminiferal zones instead. The Paleocene is divided on the basis of its planktonic Foraminifera into the following three zones ; the *Globorotalia compressa/Globigerina daubjergensis* Zone, the *Globorotalia angulata* Zone and the *Globorotalia velascoensis* Zone. These are taken to represent the Lower Paleocene (or the Danian), the Middle Paleocene, and the Upper Paleocene respectively. The assignment of either of the last two zones to the Montian, Thanetian, Sparnacian, Landenian or Ilerdian, as suggested by various authors, is rather arbitrary, and is not based on proper correlation with the type sections.

7. The term " Ilerdian " should be dropped from Paleocene stratigraphy as it is very misleading.

8. The Paleocene–Eocene boundary is marked by the complete disappearance of *Globorotalia velascoensis velascoensis* (Cushman) and its associated fauna, by the first appearance of *Globorotalia bollii* sp.nov., and by the flood of *Globorotalia wilcoxensis* Cushman & Ponton.

9. The basal Eocene is marked by the *Globorotalia wilcoxensis* Zone. The relationship between the Ypresian and the Cuisian is not yet completely understood ; the term Ypresian appears to be more appropriate inasmuch as the type Ypresian also includes the Cuisian, but the fact that the planktonic Foraminifera in these type stages are not correctly known, neccesitates the temporary abandonment of these terms.

NB For simplicity all faunal zones are represented on this chart by equal distances, although this does not mean that they are of equal thickness

FIG. 16 Distribution of Planktonic Foraminifera in the Maestrichtian-Lower Eocene formations of the Esna-Idfu Region

SYSTEM
CRETACEOUS
TERTIARY
SERIES
UPPER CRETACEOUS
PALEOCENE
EOCENE
STAGE
SENONIAN
MAESTRICHTIAN
LOWER PALEOCENE (DANIAN)
MIDDLE PALEOCENE
UPPER PALEOCENE
LOWER EOCENE
SUBSTAGE
CAMPANIAN
LOWER MAESTRICHTIAN
MIDDLE MAESTRICHTIAN
UPPER MAESTRICHTIAN
UPPER DANIAN
GROUP
ESNA
SHALE GROUP
LIBYA GROUP
FORMATION
SIBAIYA formation
SHARAWNA formation
OWAINA formation
MEMBER
LOWER SHARAWNA shale
MIDDLE SHARAWNA marl
UPPER SHARAWNA shale
LOWER OWAINA shale
MIDDLE OWAINA chalk
UPPER OWAINA shale
THEBES calcareous shale
THEBES limestone
MACRO-FAUNAL ZONE
Lopha villei zone
Pecten (Chlamys) mayer-eymari zone
Caryosmilia granosa zone
Ostrea hypoptera zone
Non Mega-Fossiliferous zone
Lucina the baica zone
MACRO-FAUNAL SUBZONE
Terebratulina gracilis subzone
Pecten (Chlamys) mayer-eymari subzone
Libycoceras berisensis subzone
MACRO-FAUNAL ZONE
Globotruncana fornicata zone
Globotruncana gansseri zone
Globotruncana esnehensis zone
G. compressa/G. daubjergensis zone
Globorotalia angulata zone
Globorotalia velascoensis zone
Globorotalia wilcoxensis
MACRO-FAUNAL SUBZONE
G. uncinata subzone
G. pusilla subzone
G. pseudomenardii subzone
G. aequa/G. esnaensis subzone
Disconformity
PORIFERA
COELENTERATA
BRACHIOPODA
MOLLUSCA
PELECYPODA
GASTROPODA
CEPHALOPODA
ECHINODERMATA
CHORDATA VERTEBRATA
Schizorhabdus libycus ZITTEL 1
Brachycyathus danienais WANNER 2
Caryosmilia granosa WANNER 3
Caryophyllia jasmundi WANNER 4
Dungulia libyca (WANNER) 5
Palaeopsammia multiformis WANNER 6
Palaeopsammia zitteli WANNER 7
Psittalophyllia aegyptiaca WANNER 8
Thecocyathus aegyptiacus WANNER 9
Trochocyathus epicharis WANNER 10
Ventriculites poculum ZITTEL 11
Terebratula libyca WANNER 12
Terebratula sp. 13
Terebratulina chrysalis SCHLOTHEIM 14
Terebratulina cf. dutempleana D'ORBIGNY 15
Terebratulina gracilis SCHLOTHEIM 16
Angulus wanneri ABBASS 17
Arca (Barbatia) esnehensis (NEWTON) 18
Arca (Cucullaea) schweinfurthi (ZITTEL) 19
Arca (Macrodon) dupiniana (D'ORBIGNY) 20
Arca (Trigonoarca) multidentata BULLEN-NEWTON 21
Arca Modioloides WANNER 22
Astarte (Tridonta) gigantea (DESHAYES) 23
Brachydontes (Septifer) jordani (QUAAS) 24
Cardita aegyptiaca FRAAS 25
Cardita schweinfurthi OPPENHEIM 26
Cardium cf. beckeli J. MULL 27
Corbula (Corbula) dakhlensis ABBASS 28
Corbula (Bicorbula) prae-exarata COX 29
Crassatella (Anthonia) awadi ABBASS 30
Crassatella (Scambula) chargensis QUAAS 31
Crassatella (Scambula) matercula MAYER-EYMAR 32
Dimya libyca QUAAS 33
Gryphaea pharaonum OPPENHEIM 34
Gryphaea pharaonum var. quadrata OPPENHEIM 35
Isocardia (Isocardia) chargehensis MAYER-EYMAR 36
Leda zitteli J. BOHM 37
Limea delanouei OPPENHEIM 38
Limopsis awadi ABBASS 39
Liopistha libyca QUAAS 40
Lopha forgemoli (COQUAND) 41
Lopha lunata (NILSSON) 42
Lopha ungulata (SCHLOTHEIM) 43
Lopha villei (COQUAND) 44
Lucina (Dentilucina) dachelensis (WANNER) 45
Lucina edita OPPENHEIM 46
Lucina qurnaensis OPPENHEIM 47
Lucina (Miltha) saharica (QUAAS) 48
Lucina thebaica ZITTEL 49
Lucinopsis newtoni ABBASS 50
Meretrix rohlfsi (QUAAS) 51
Nucula (Nucula) chargensis QUAAS 52
Nucula (Nucula) moradi ABBASS 53
Nucula (Acila) farisi ABBASS 54
Nucula (Acila) tremolate-striata (WANNER) 55
Nuculana (Jupiteria) protexta (GABB) 56
Ostrea aucapitainei COQUAND 57
Ostrea cortex CONRAD 58
Ostrea hypoptera (WANNER) 59
Ostrea multicostata DESHAYES 60
Ostrea nicaisei COQUAND 61
Ostrea renoui COQUAND 62
Ostrea scaniensis COQUAND 63
Pecten (Chlamys) mayer-eymari BULLEN-NEWTON 64
Pholadomya cf. lucerna FORBES 65
Pholadomya saidi ABBASS 66
Plicatula numidica COQUAND 67
Plicatula pausicostata SEGUENZA 68
Protocardia moabitica LARTET 69
Pycnodonta vesicularis (LAMARCK) 70
Roudaireia arabica ABBASS 71
Roudaireia awadi ABBASS 72
Roudaireia dakhlensis ABBASS 73
Roudaireia drui MUNIER-CHALMAS 74
Spondylus aegyptiacus BULLEN-NEWTON 75
Spondylus latus (SOWERBY) 76
Thyasira (Thyasira) cretacea (WANNER) 77
Venericardia leirensis AWAD 78
Actaeon lorioli QUAAS 79
Alaria schweinfurthi QUAAS 80
Alaria cf. schweinfurthi QUAAS 81
Cerithium abietiforme WANNER 82
Caritherium dachelense WANNER 83
Cerithium periphractum WANNER 84
Dentalium bicarinatum WANNER 85
Dilphinula zitteli QUAAS 86
Erato sp. QUAAS 87
Fasciolaria (Odontofusus) densiplicata ZITTEL 88
Fasciolaria (Odontofusus) rohlfsi ZITTEL 89
Natica farafrensis WANNER 90
Natica (Euspira) pagoda FORBES 91
Natica sp. QUAAS 92
Natica (Euspira) sp. HASSAN 93
Pleurotoma (Surcula) libyca QUAAS 94
Pyrgopolon pomeli QUAAS 95
Ringicula ptahis WANNER 96
Scalaria desertorum WANNER 97
Scalaria jasmundi WANNER 98
Solarium dachelense WANNER 99
Tornatellaea pharaonum WANNER 100
Turritella aegyptiaca MAYER-EYMAR 101
Turritella imbricataria LAMARCK 102
Turritella sexlineata ROEMER 103
Turritella (Torcula) beyrichi QUAAS 104
Turritella (Torcula) gemina STOLICZKA 105
Turritella (Torcula) overwegi QUAAS 106
Turritella (Torcula) sp. QUAAS 107
Voluta (Scaphella) aegyptiaca WANNER 108
Voluta sp. QUAAS 109
Volutilithes desertorum QUAAS 110
Baculites ex gr. anceps LAMARCK 111
Libycoceras sp. cf. Libycoceras ismaeli ZITTEL 112
Libycoceras berisensis AWAD and NAIM 113
Nautilus applanatus ZITTEL 114
Nautilus desertorum ZITTEL 115
Nautilus? jordani ZITTEL 116
Nautilus schweinfurthi ZITTEL 117
Nautilus tamulicus KOSSMAT 118
?Bourgueticrinus sp. QUAAS 119
Conoclypeus delanoui DE LORIOL 120
Linthia ascherseni DE LORIOL 121
Linthia cavernosa DE LORIOL 122
Linthia delanouei DE LORIOL 123
Linthia esnehensis DE LORIOL 124
Pentacrinus sp. QUAAS 125
Rhabdocidaris (libyensis) libyca GREGORY (FOURTAU) 126
Schizaster thebensis DE LORIOL 127
Ancistrodon libycus DAMES 128
Anomoeodus angustus (Agassiz) WOODWARD 129
Corax bassanii (Gamellaro) AGASSIZ 130
Corax pristodontus AGASSIZ 131
Lamna appendiculata AGASSIZ 132
Lamna rapax ZITTEL 133
Lamna libyca ZITTEL 134
Otodus biauriculatus ZITTEL 135
Otodus serratus AGASSIZ 136
Otodus smilodon ZITTEL 137
Plethodus sp. DIXON 138
Rhombodus sp. DAMES 139
Schizorhiza stromeri STROMER 140
Stephanodus libycus DAMES 141
Globidens aegyptiacus ZDANSKY 142

FIG. 17. Distribution of Macrofauna in Upper Campanian–Lower Eocene formations of the Esna-Idfu Region.

Correction: *Ventriculites poculum* Zittel should be included under Porifera.

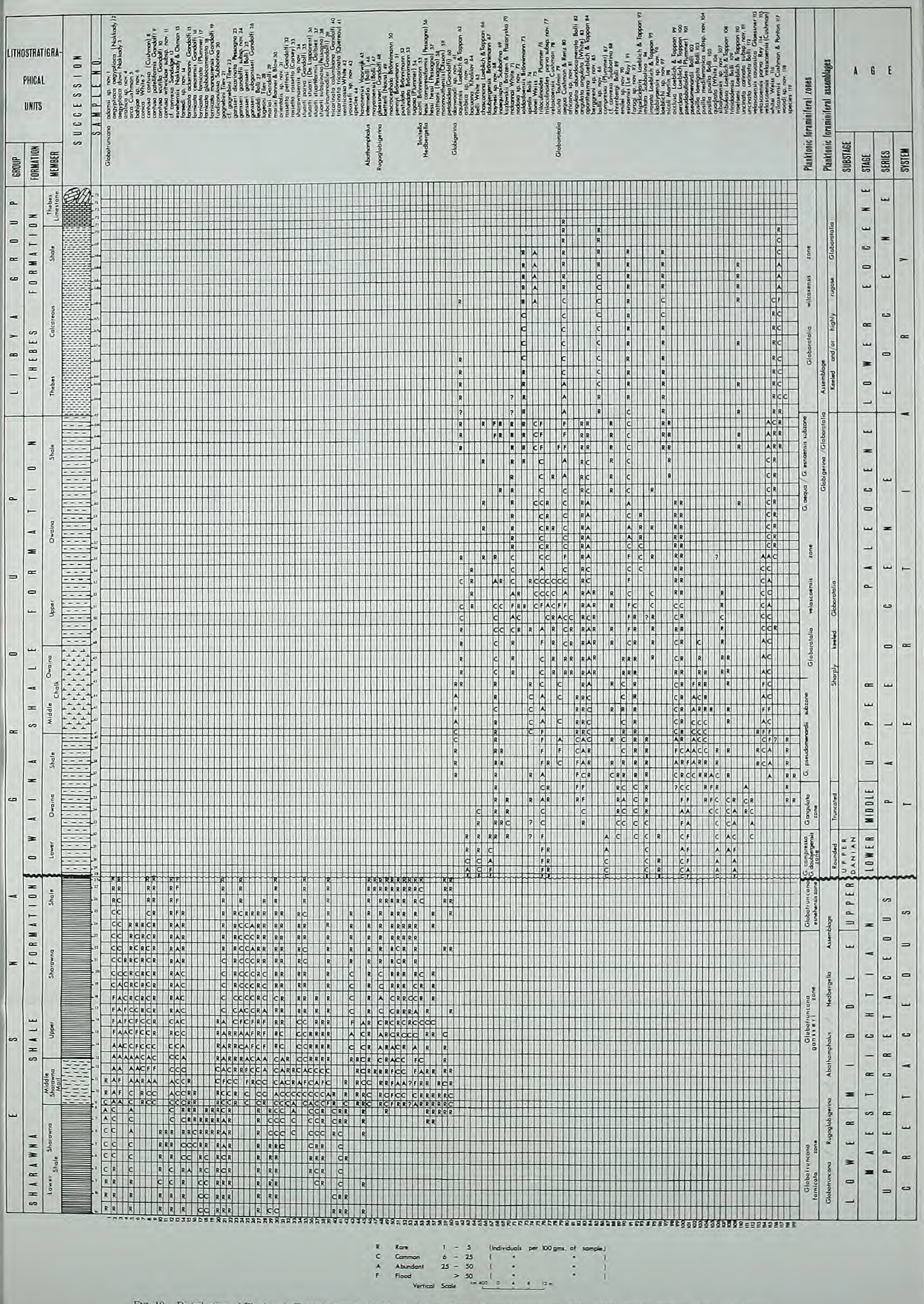


FIG. 18. Distribution of Planktonic Foraminifera in the Maestrichtian–Lower Eocene formations of the Gebel Owaina Section, Esna-Idfu Region.

N.B.
1. The Lower Sharawna shale member is not fully developed in this section, but can be clearly seen to the west and south of the G. Owaina massif in the W. El-Sharawna section and its environs.
2. The *Globotruncana fornicata* Zone is better developed in the Abou Saboun and the △ 314 sections.
3. The conglomerate separating the Maestrichtian from the overlying Paleocene is better developed in the G. El-Kilabiya and the G. El-Sharawna sections.
4. The two records of *Globorotalia woodi* shown in the upper part of the Middle Paleocene, should be removed to the uppermost part of the Upper Paleocene.

APPENDIX

While this work was in press, Said & Sabry published their work on " Planktonic Foraminifera from the type locality of the Esna Shale in Egypt " (*Micropaleontology*, **10** : 375–395, pls. 1–3), and the following comments are made on the results of their study:

A. Concerning their biostratigraphical zonation.

(1). Owing to their limited study, Said & Sabry have ignored the varied planktonic foraminiferal fauna of the Maestrichtian and in addition to the fact that practically all their *Globotruncana* species are wrongly identified they have overlooked the following forms which characterize the Maestrichtian part of the succession :

Globotruncana adamsi sp. nov.
G. arabica sp. nov.
G. bahijae sp. nov.
G. conica White
G. contusa contusa (Cushman)
G. contusa patelliformis Gandolfi
G. contusa scutilla Gandolfi
G. contusa witwickae subsp. nov.
G. cf. *convexa* Sandidge
G. esnehensis Nakkady & Osman
G. fareedi sp. nov.
G. fornicata ackermanni Gandolfi
G. fornicata cesarensis Gandolfi
G. fornicata fornicata Plummer
G. fornicata globulocamerata subsp. nov.
G. fornicata manaurensis Gandolfi
G. fundiconulosa Subbotina
G. gagnebini Tilev
G. cf. *gagnebini* Tilev
G. gansseri dicarinata Pessagno
G. gansseri gandolfii subsp. nov.
G. gansseri gansseri Bolli
G. gansseri subgansseri Gandolfi
G. havanensis Voorwijk
G. leupoldi Bolli
G. lugeoni Tilev
G. mariai Gandolfi
G. mariei Banner & Blow
G. orientalis sp. nov.
G. rosetta pettersi Gandolfi
G. sharawnaensis sp. nov.
G. stuarti parva Gandolfi
G. stuarti stuartiformis Dalbiez
G. stuarti subspinosa Pessagno
G. subcircumnodifer Gandolfi
G. tricarinata colombiana Gandolfi
G. tricarinata tricarinata (Quereau)
G. ventricosa White
G. youssefi sp. nov.
Rugoglobigerina glaessneri Gandolfi
R. loetterli (Nauss)
R. macrocephala Brönnimann
R. pennyi Brönnimann
R. rotundata Brönnimann
A. mayaroensis (Bolli)

Trinitella scotti Brönnimann
Abathomphalus intermedia (Bolli)

(2). In their treatment of the Paleocene–Lower Eocene succession they have almost literally followed Bolli's (1957*b*) zonation, but their failure to recognize both *Globorotalia trinidadensis* Bolli and *G. compressa* (Plummer) which flood the basal part of the Paleocene has led them to discuss " a *Globigerina daubjergensis–Globorotalia pseudobulloides* zone ". *Globorotalia pseudobulloides*, however, ranges throughout the Paleocene and cannot, therefore, be used for its subdivision. Their figured *Globigerina daubjergensis* Brönnimann (pl. 3, figs. 8*a–c*) does not belong to this species.

Their references (p. 384, pl. 1, figs. 16*a–c* and p. 388, no figs.) to a Lower Landenian *Globorotalia pseudobulloides* (Plummer) and a Danian *Globigerina pseudobulloides* Plummer is rather confusing as both include Plummer's holotype (1926 : 133, pl. 8, figs. 9*a–c*) in the relevant synonymies.

(3). Following Bolli (1957*b*) they mention a " *Globorotalia uncinata* zone ". However, *G. uncinata*, as seen in the present study, occurs in the upper part of the " *Globorotalia compressa/Globigerina daubjergensis* Zone " and continues almost to the base of the " *G. velascoensis* Zone ". It floods the lower part of the " *G. angulata* Zone" and is only taken to characterize this part as a distinct subzone. They also refer to the occurrence in this zone of *Globorotalia compressa* (Plummer) and *Globorotalia colligera* (Schwager) among others, although *G. compressa* is restricted to the Danian and *G. colligera* was originally described from the Lower Eocene.

(4). Again, following Bolli (1957*b*) they refer to a " *Globorotalia pusilla pusilla* Zone ", stating that this subspecies marks a zone at the base of the Landenian to which it is restricted, while the other subspecies *G. pusilla laevigata* only exists in the basal Eocene. However, in the present study *G. pusilla pusilla* was found to flood the upper part of the " *G. angulata* Zone ", characterizing a particular subzone, and to fade out gradually into the basal part of the overlying " *G. velascoensis* zone ", while *G. pusilla laevigata* ranges throughout the lower part of the latter zone, but not in the Lower Eocene. They state (p. 380) that " The topmost 10 metres of the Dakhla shale of Gebel Aweina are characterized by a number of *Globorotalia* species that belong to the sharply keeled forms : *G. pusilla pusilla, G. angulata, G. perclara, G. ehrenbergi, G. triplex* and *G. simulatilis* ...", none of which is a sharply keeled form.

(5). Like Bolli (1957*b*) they mention a " *Globorotalia pseudomenardii* zone " and a " *Globorotalia velascoensis* zone ". The present study, however, showed that the two species appear for the first time together and the former only characterizes the lower part of a zone distinguished by the latter species. They also mention the existence in the " *G. velascoensis* zone " of *Globorotalia broedermanni* Cushman & Bermudez, a known Lower–Middle Eocene form. Moreover, they extend the range of *G. velascoensis* to cover 76 ms. above the chalk, while the species has been found in the present study to die out completely at a vertical distance of 60 ms. from the top of the chalk.

(6). Because of their uncertainty, they state (p. 380) : " The age of the above mentioned four zones is interpreted as Landenian, although the *G. pusilla* and *G. pseudomenardii* zones could well be Montian, in which case the *G. uncinata* zone might be either Danian or Montian ".

(7). They refer to a " *Globorotalia rex* zone " of Ypresian age, although their figured *G. rex* Martin (p. 385, pl. 2, figs. 3*a–c*) is possibly *G. bollii* El-Naggar. They also record the occurrence of *G. pusilla laevigata* Bolli and *G. conicotruncata* Subbotina in their " *G. rex* zone ". The former species is restricted to the lower part of the Upper Paleocene, while the latter is probably synonymous with the definitely Paleocene *G. angulata abundocamerata* Bolli.

B. CONCERNING THEIR DETERMINATIONS OF PLANKTONIC FORAMINIFERA :

(1). *Praeglobotruncana coarctata* Bolli (p. 381, pl. 3, fig. 23) is *Rugoglobigerina macrocephala* Brönnimann ; Bolli's species is morphologically and stratigraphically distinct and has only been recorded from the Lower Campanian.

(2). *Globorotalia aequa* Cushman & Renz (pp. 381, 382, pl. 2, fig. 8) is a keeled form while the holotype and hypotypes in the present study are not at all keeled. They appear to have lumped several other forms within their *G. aequa* such as *G. loeblichi* El-Naggar. This is clear from their description (p. 382) " . . . . . peripheral margin sharply angled, sometimes with a well developed keel ; . . . . . umbilicus wide ; . . . . . keel and spiral sutures thickened and nodose ; ventral side smooth ".

(3). *Globorotalia angulata* (White) (p. 382, pl. 1, fig. 3) is probably a transitional stage to *G. angulata abundocamerata* Bolli ; it is a keeled form with five chambers in the last whorl while White's holotype is typically non-keeled. Their *Globorotalia conicotruncata* (Subbotina) (p. 383, pl. 2, fig. 7) is probably *G. angulata angulata* (White).

(4). *Globorotalia broedermanni* Cushman & Bermudez (p. 382, pl. 1, fig. 4) differs from the holotype in being much larger, flatter on the dorsal side and less tightly coiled.

(5). *Globorotalia colligera* (Schwager) (p. 382, pl. 1, fig. 14) does not belong to this species ; Schwager's form was recorded from younger strata and the holotype needs to be redrawn and redescribed in more detail.

(6). *Globorotalia compressa* (Plummer) (p. 382, pl. 3, fig. 13) probably belongs to *Globorotalia emilei* El-Naggar. *Globorotalia compressa* is restricted to the Danian, while their form comes from the Lower Landenian.

(7). *Globorotalia convexa* Subbotina (p. 383, pl. 3, fig. 17) differs from the holotype in having fewer chambers and in lacking a concave, bulla-like last chamber. It probably belongs to the form described in the present study as *Globorotalia* cf. *convexa*.

(8). *Globorotalia imitata* Subbotina (p. 383, pl. 3, fig. 6) differs from the holo- and paratypes of Subbotina and the hypotypes of the present study in being much flatter on the dorsal side, more protruding on the ventral, having more acute axial periphery and less inflated chambers. The forms recorded in the present study agree well with Subbotina's original description and figures.

(9). *Globorotalia interposita* (Subbotina) (p. 383, pl. 1, fig. 15) does not belong to this species. *Acarinina interposita* Subbotina is a synonym of *Globigerina soldadoensis* Brönnimann.

(10). *Globorotalia lensiformis* Subbotina (p. 383, pl. 2, fig. 2) is *Globorotalia occlusa* Loeblich & Tappan. Subbotina's form was described from the Lower–Middle Eocene while their form is recorded from the Upper Landenian.

(11). *Globorotalia pentacamerata* (Subbotina) (p. 384, pl. 1, fig. 6) is probably a deformed specimen of *Globigerina mckannai* White.

(12). *Globorotalia planoconica* Subbotina (p. 384, pl. 3, fig. 12) apparently includes forms related to both *Globorotalia emilei* El-Naggar and *G. troelseni* Loeblich & Tappan. Subbotina's form was originally described from the Lower–Middle Eocene while theirs comes from the Upper Landenian–Ypresian.

(13). *Globorotalia pseudobulloides* (Plummer) (p. 384, pl. 1, fig. 16) seems doubtful because of their description of the chambers as compressed and of the surface as smooth. Their form is stated to occur in the " *G. uncinata* zone " while *G. pseudobulloides* ranges throughout the Paleocene.

(14). *Globorotalia pseudoscitula* Glaessner (p. 384, pl. 2, fig. 1) is quite distinct from Glaessner's form. Judging from their figure and very brief description, it may well belong to *Globorotalia pusilla laevigata* Bolli although it appears to be much larger.

(15). *Globorotalia pseudotopilensis* (Subbotina) (pp. 384, 385, pl. 1, fig. 9) is very different from Subbotina's form which in any case is a junior synonym of *Globorotalia esnaensis* (Le Roy). It probably belongs to *Globorotalia tribulosa* Loeblich & Tappan.

(16). *Globorotalia pusilla laevigata* Bolli (p. 385, pl. 3, fig. 7) belongs to *Globorotalia woodi* El-Naggar.

(17). *Globorotalia quadrata* Nakkady & Talaat (p. 385, pl. 1, fig. 10) belongs to *Globorotalia quadrata* (White).

(18). *Globorotalia rex* Martin (p. 385, pl. 2, fig. 3) belongs to *Globorotalia bollii* El-Naggar.

(19). *Globorotalia simulatilis* (Schwager) (p. 385, pl. 1, fig. 1) probably belongs to *Globorotalia angulata abundocamerata* Bolli. *G. simulatilis* was originally described from younger strata and its holotype needs to be redrawn and redescribed in more detail.

(20). *Globorotalia triplex* (Subbotina) (p. 385, pl. 1, fig. 8) differs from Subbotina's holotype of *Acarinina triplex* which is probably *Globigerina velascoensis* Cushman.

(21) *Globorotalia varianta* (Subbotina) (p. 386, pl. 3, fig. 9) probably belongs to *Globorotalia* cf. *convexa* of the present study. *Globigerina varianta* Subbotina is a different form which probably includes *Globorotalia pseudobulloides* (Plummer), *Globorotalia quadrata* (White) and *Globorotalia esnaensis* (Le Roy).

(22). *Globorotalia velascoensis* (Cushman) (p. 386, pl. 2, fig. 9) is probably a transitional form between *Globorotalia angulata abundocamerata* Bolli and *Globorotalia velascoensis velascoensis* (Cushman).

(23). *Globorotalia wilcoxensis* Cushman & Ponton (p. 386, pl. 3, fig. 14) probably belongs to *Globorotalia whitei* Weiss.

(24). *Rugoglobigerina bulbosa* Belford (p. 386, pl. 3, fig. 15) probably belongs to *Rugoglobigerina rugosa* (Plummer).

(25). *Rugoglobigerina reicheli pustulata* Brönnimann (p. 386, pl. 3, fig. 16) is a doubtful form. It is described as having a smooth surface while the holotype is extremely rough and coarsely rugose.

(26). *Globotruncana aegyptiaca* Nakkady (pp. 386, 387, pl. 3, fig. 1) does not belong to this species. It is described as single-keeled while the holo- and paratypes of Nakkady, as well as the hypotypes of the present study, are entirely double-keeled. Probably the form is double-keeled and, if so, it should be attributed to *Globotruncana gagnebini* Tilev as can be seen from their figures.

(27). *Globotruncana aegyptiaca* var. *duwi* Nakkady (p. 387, pl. 3, fig. 2) is shown to have a single keel although the holo- and paratypes of Nakkady, as well as hypotypes in the present study, are entirely double-keeled.

(28). *Globotruncana arca* (Cushman) (p. 387, pl. 2, fig. 5) belongs to *Globotruncana gagnebini* Tilev.

(29). *Globotruncana cretacea* Cushman (p. 387, pl. 3, fig. 4) is probably a deformed specimen of *Globotruncana stuarti stuarti* (de Lapparent). It is described as being biconvex and single-keeled while Cushman's form, as re-examined by Brönnimann & Brown (1956), has two keels in all chambers of the last whorl.

(30). *Globotruncana gansseri* Bolli (p. 387, pl. 3, fig. 3) is a doubtful form. It is described as having a distinct and keeled umbilical shoulder and an aperture with perforate tegilla. It is not really known what is meant by keeled umbilical shoulder or perforate tegilla as the latter are always imperforate. Again, while they described the chamber number as 5–6 in the last whorl, their figured specimen shows only $3\frac{1}{2}$ chambers.

(31). *Globotruncana rosetta* (Carsey) (p. 387, pl. 3, fig. 5) is shown to have an entirely single keel while the holotype is characterized by two closely spaced keels on the early part of the last whorl (see Brönnimann & Brown 1956).

(32). *Globotruncana stuarti* (de Lapparent) (p. 387, pl. 2, fig. 3) belongs to *Globotruncana conica* White.

(33). *Globigerina daubjergensis* Brönnimann (p. 387, pl. 3, fig. 8) does not belong to this species. It is much larger, less raised on the dorsal side and has fewer chambers in the last whorl which increase more rapidly than in the typical form. It is probably *Globigerina triloculinoides* Plummer.

(34). *Globigerina inaequispira* Subbotina (p. 387, pl. 3, fig. 10) is a doubtful form which differs markedly from the holotype.

(35). *Globigerina pseudobulloides* Plummer (p. 388, no figs.) is a very confusing record as the authors also recorded what they describe as *Globorotalia pseudobulloides* (Plummer) in the same study.

(36). *Globigerina quadrata* White (p. 388, pl. 3, fig. 22) is clearly shown in their figure to have an extraumbilical aperture although included by them in the genus *Globigerina*.

C. Concerning their lithostratigraphical zonation.

Following Ghorab (1956) and Said (1961, 1962) they have used the term Dakhla shale as a substitute for the older term Lower Esna shale. The Dakhla shale, as originally designated, includes the Maestrichtian Sharawna shale, the conglomerate separating it from the overlying Paleocene Owaina shale, and the lower part of the latter formation. These varied, lithological and palaeontological units, which are clearly separated by a marked break, cannot be treated as one formation. Thus, the term Dakhla shale is here dropped and the classification of the Esna group into a Lower Sharawna formation and an Upper Owaina formation is here suggested.

They have treated the chalk separately and restricted the Esna shale to the succession of strata between the chalk and the base of the Thebes formation which is here assigned to the Upper Owaina shale member. However, this restricted use of the term is contrary to the original usage and conflicts with the lithological relationships of the various units in the field as well as with their palaeontological continuity.

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PLATE 1

(All figures approximately × 80)

a, dorsal view ; b, side view ; c, ventral view

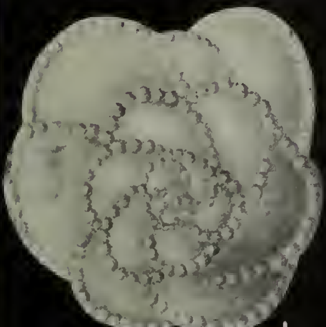
Figs. 1a–c, 2. ***Globotruncana arca*** (Cushman). Hypotypes, from S.4, Abou Saboun section, showing variation in the degree of development of the ventral keel on the last chambers. P.45517

Figs. 3a–c. Transitional stage between ***Globotruncana arca*** (Cushman), and ***Globotruncana convexa*** Sandidge ; from S.23, W. El-Sharawna section. P.45517

Figs. 4a–c. ***Globotruncana leupoldi*** Bolli. Hypotype, from S.18, W. El-Sharawna section. P.45545

Figs. 5a–c. ***Globotruncana*** cf. ***convexa*** Sandidge. Hypotype, from S.20, W. El-Sharawna section. P.45526

Figs. 6a–c. ***Globotruncana*** sp., from S.20, W. El-Sharawna section. P.45566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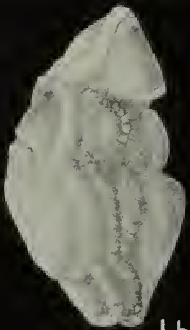
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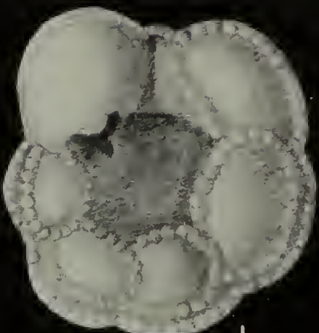
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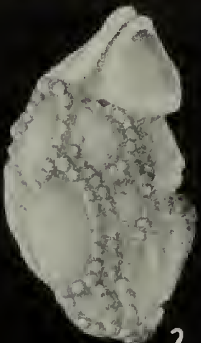
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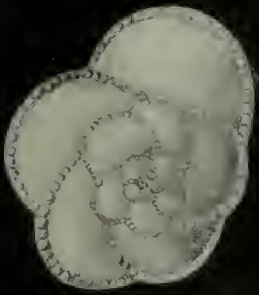
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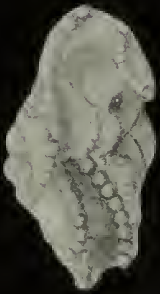
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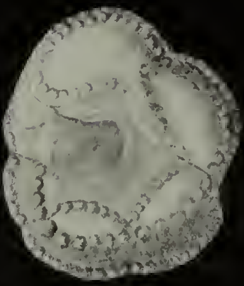
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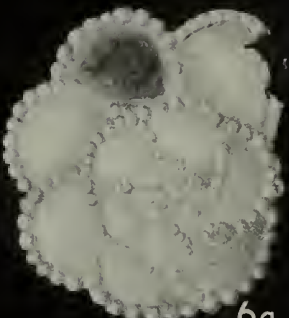
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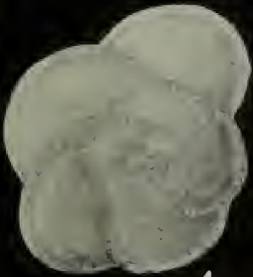
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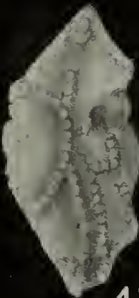
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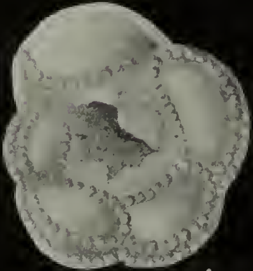
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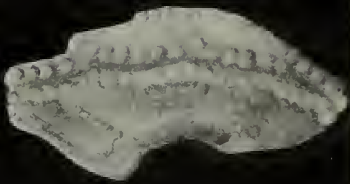
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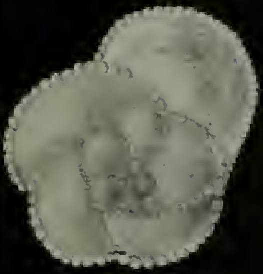
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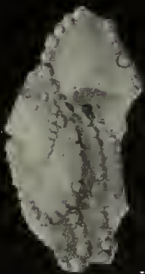
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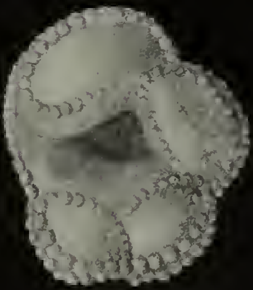
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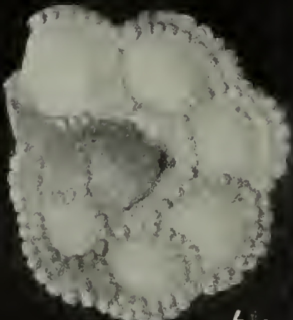
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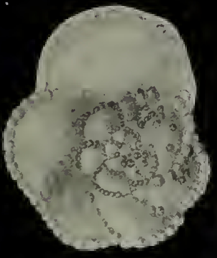
PLATE 2

(All figures approximately ×71)

a, dorsal view ; b, d, side views ; c, ventral view

FIGS. 1a–4d. ***Globotruncana gagnebini*** Tilev. Hypotypes 1 and 2, from S.16, W. El-Sharawna section ; hypotype 3 which is a transitional stage to ***G. ventricosa*** White, is from S.18, W. El-Sharawna section ; hypotype 4 from S.4, Abou Saboun section. P.45538, P.45539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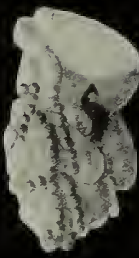
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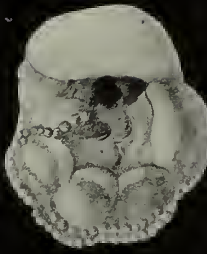
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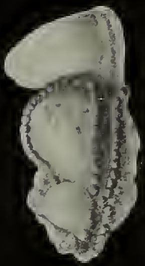
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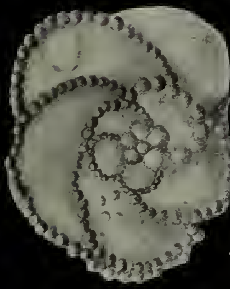
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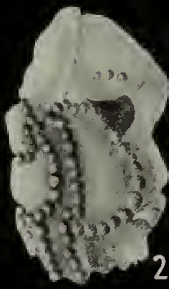
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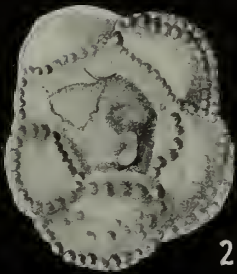
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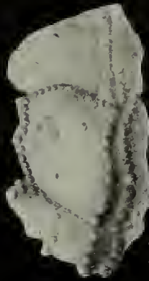
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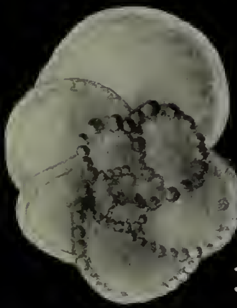
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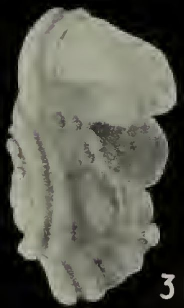
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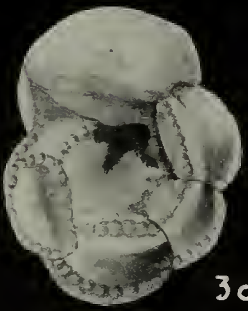
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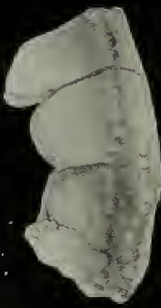
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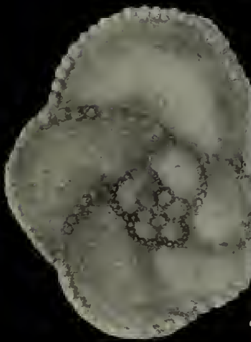
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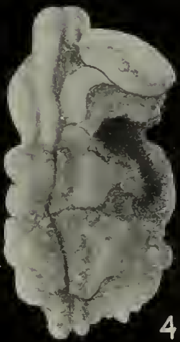
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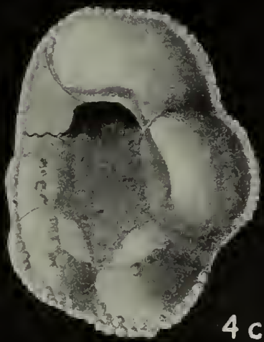
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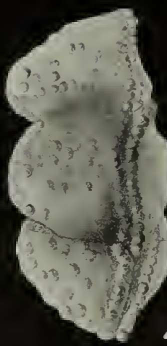
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PLATE 3

(All figures approximately × 75)
a, dorsal view ; b, d, side views ; c, ventral view

FIGS. 1a–d, 3a–d, 6. ***Globotruncana gagnebini*** Tilev. Hypotype 1, from S.11, G. Owaina section ; hypotype 3 from S.18, W. El-Sharawna section ; hypotype 6 from S.16, W. El-Sharawna section. P.45538

FIGS. 2a–d. ***Globotruncana*** cf. ***gagnebini*** Tilev, from S.4, Abou Saboun section, showing a gently coned dorsal side different from that of the typical form. P.45539

FIGS. 4a–d. ***Globotruncana aegyptiaca aegyptiaca*** (Nakkady). Hypotype, from S.16, Gebel Owaina section, showing the distinctly petalloid equatorial periphery and the cruciform arrangement of the chambers in the last whorl. P.45512

FIGS. 5a–c. ***Globotruncana aegyptiaca duwi*** Nakkady. Hypotype, from S.16, Gebel Owaina section, showing the tripartite appearance of the test, the rapid increase in size of chambers and the rough surface. P.45514

PLATE 3

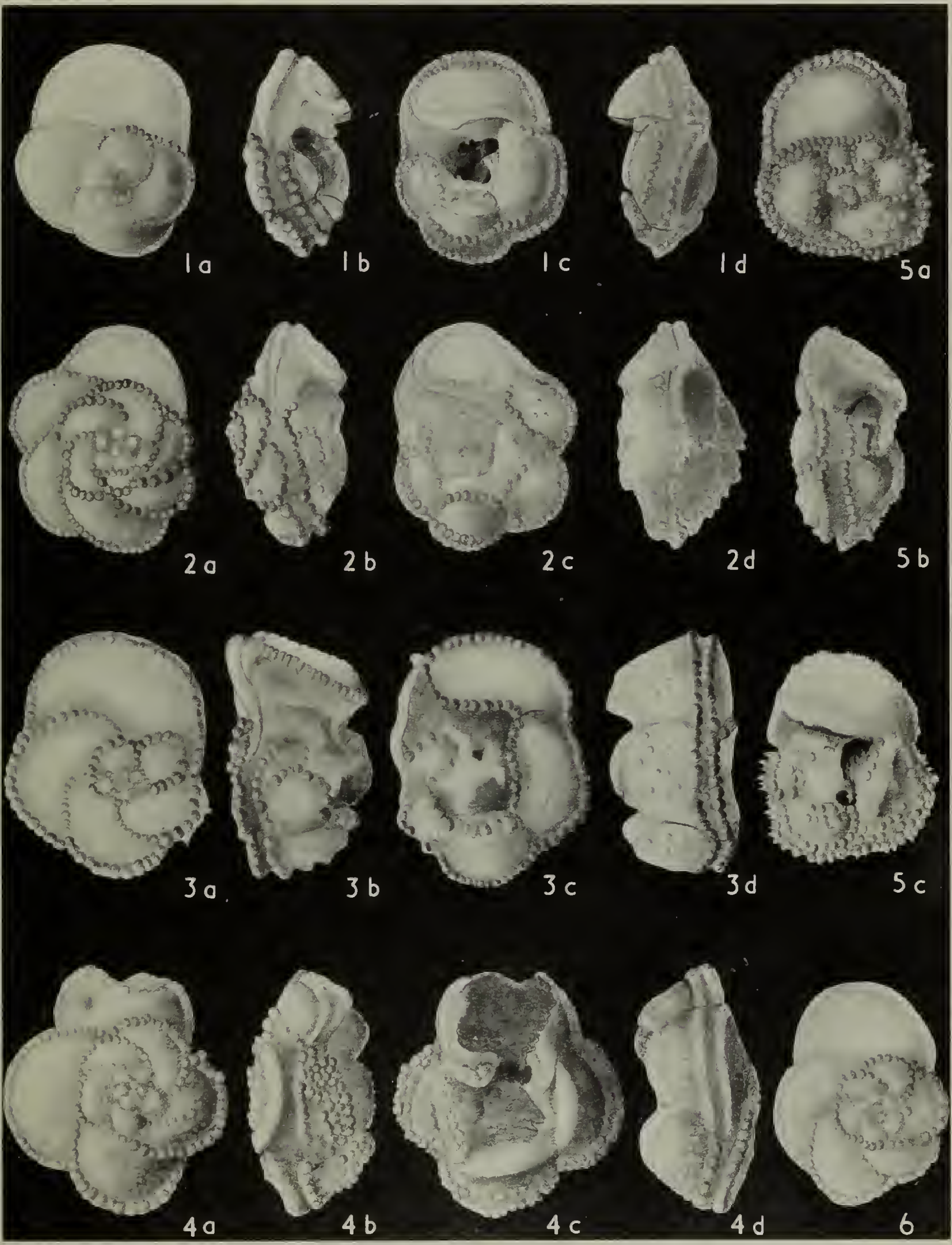


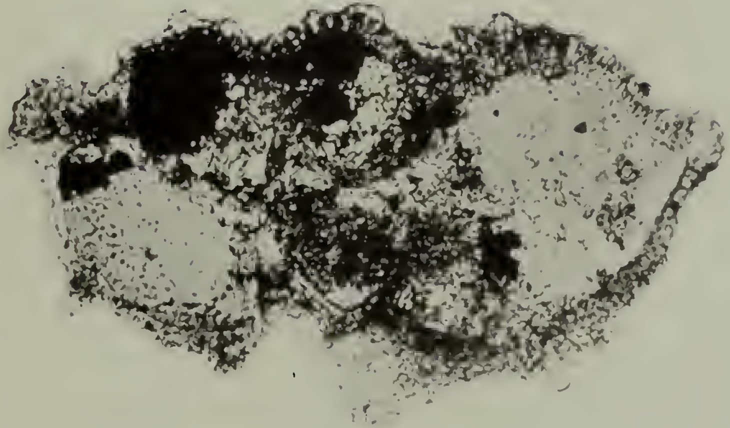
PLATE 4

Fig. 1. ***Globotruncana aegyptiaca aegyptiaca*** Nakkady, from S.16, Gebel Owaina section.

Axial section of hypotype, approximately × 247, plane polarized light.

Fig. 2. ***Globotruncana gagnebini*** Tilev, from S.17 W. El-Sharawna section.

Axial section of hypotype, approximately × 210, plane polarized light.



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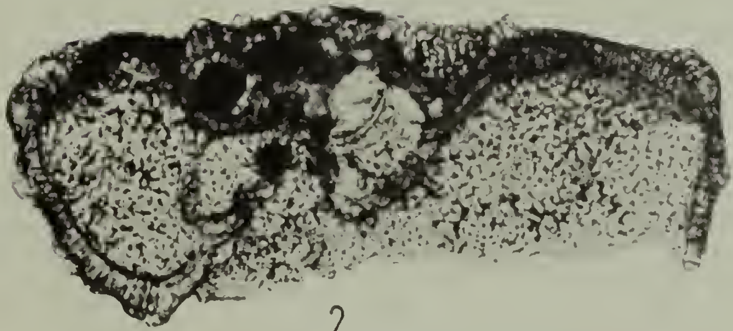


2

PLATE 5

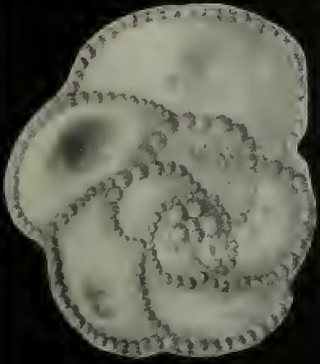
(All figures approximately × 72)
a, dorsal view ; b, d, side views ; c, ventral view

FIGS. 1a–d. ***Globotruncana gansseri gansseri*** Bolli. Hypotype, from S.18, W. El-Sharawna section. P.45543

FIGS. 2a–d. ***Globotruncana gansseri gandolfii*** subsp. nov. Holotype, from S.21, W. El-Sharawna section. P.45541

FIGS. 3a–d. ***Globotruncana gansseri subgansseri*** Gandolfi. Hypotype, from S.16, Gebel Owaina section. P.45544

FIGS. 4a–d. ***Globotruncana gansseri dicarinata*** Pessagno. Hypotype, from S.16, Gebel Owaina section. P.45540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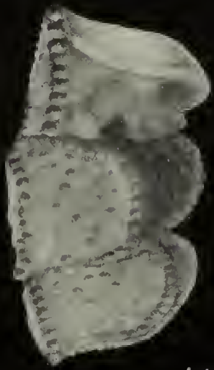
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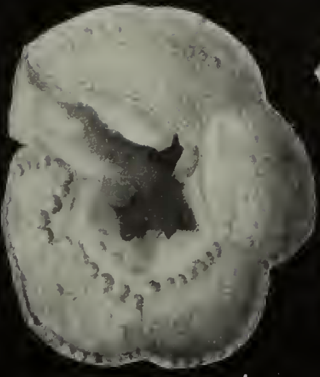
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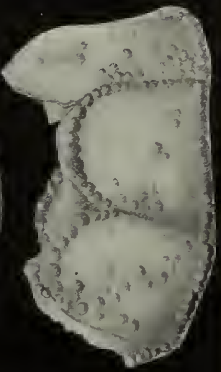
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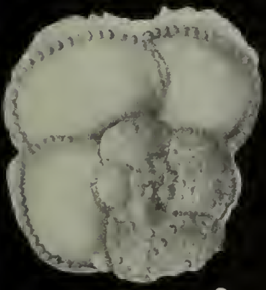
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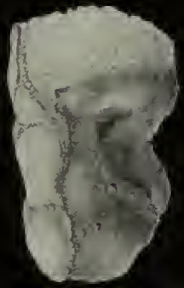
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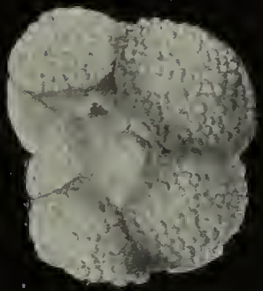
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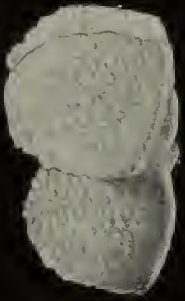
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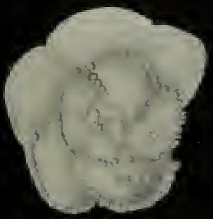
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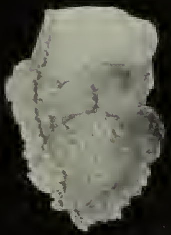
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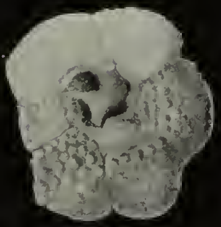
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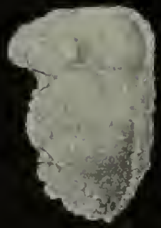
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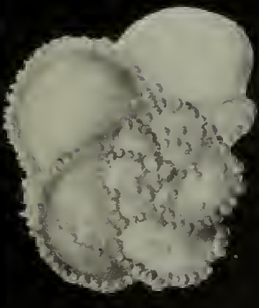
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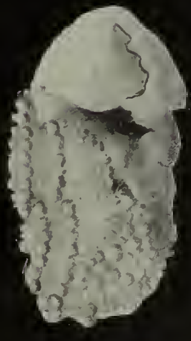
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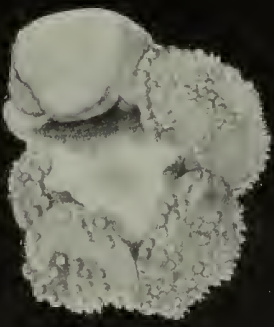
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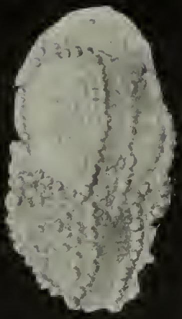

4d

PLATE 6

(All figures approximately × 80)

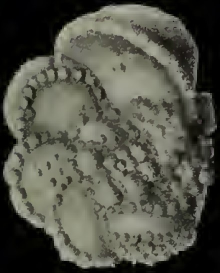
a, dorsal view ; b, d, side views ; c, ventral view

FIGS. 1a–d. ***Globotruncana lugeoni*** Tilev. Hypotype, from S.15, Gebel Owaina section. P.45546

FIGS. 2a–d. ***Globotruncana bahijae*** sp. nov. Holotype, from S.18, W. El-Sharawna section. P.45518

FIGS. 3a–d. ***Globotruncana arabica*** sp. nov. Holotype, from S.22, W. El-Sharawna section. P.45515

FIGS. 4a–d. ***Globotruncana youssefi*** sp. nov. Holotype, from S.16, Gebel Owaina section. P.45564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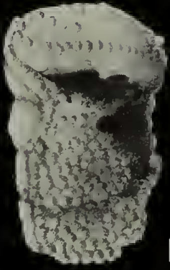
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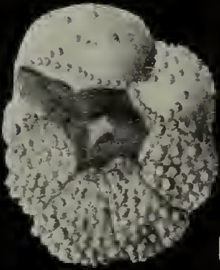
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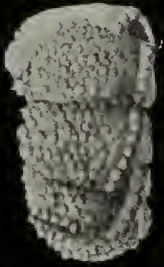
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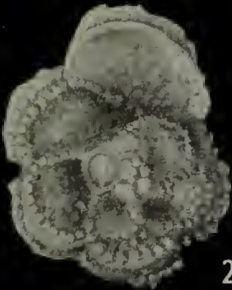
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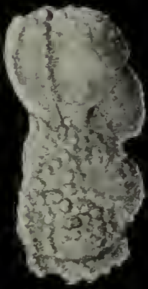
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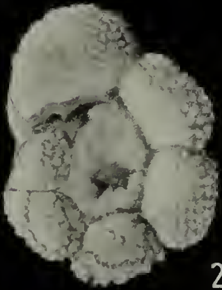
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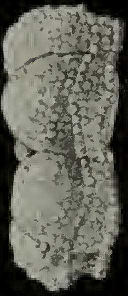
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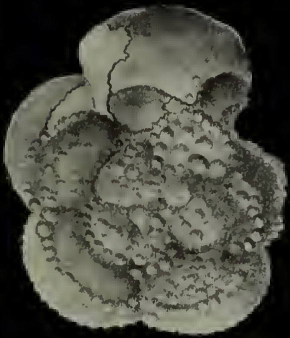
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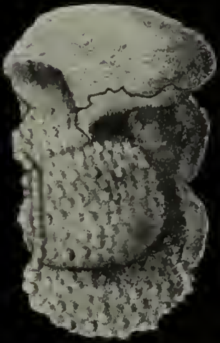
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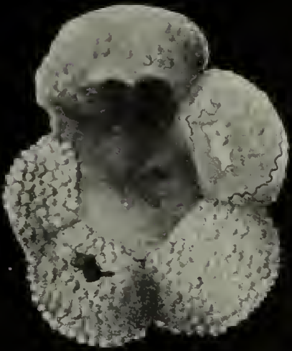
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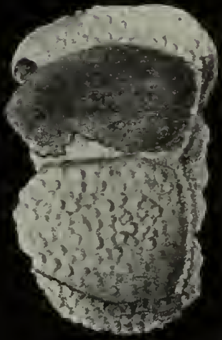
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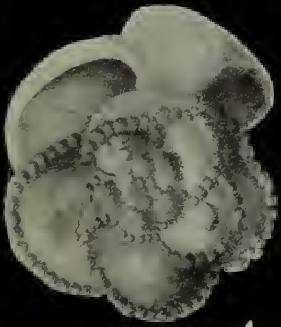
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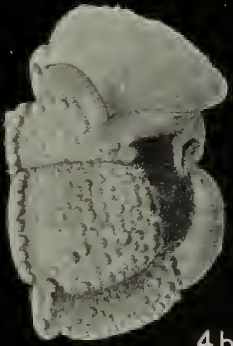
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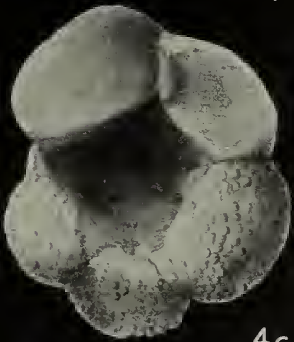
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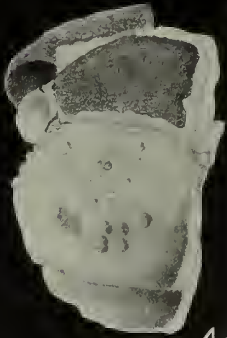
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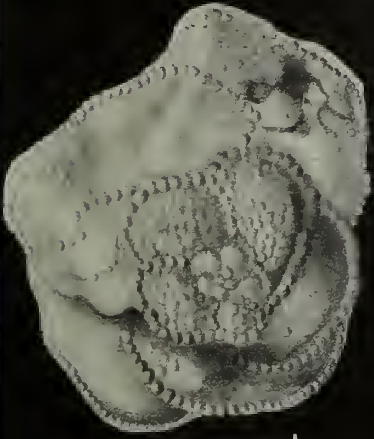
PLATE 7

(All figures approximately × 76)
a, dorsal view ; b, side view ; c, ventral view

Figs. 1a–c. ***Globotruncana contusa witwickae*** subsp. nov. Holotype, from S.4, Abou Saboun section. P.45524

Figs. 2a–3c. ***Globotruncana contusa contusa*** (Cushman). Hypotypes, from S.18, W. El-Sharawna section. P.45521



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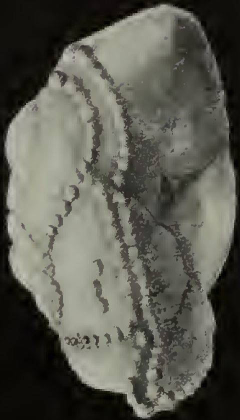

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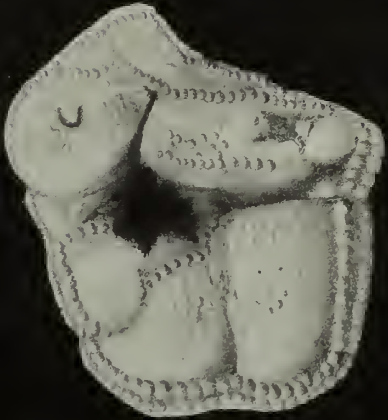

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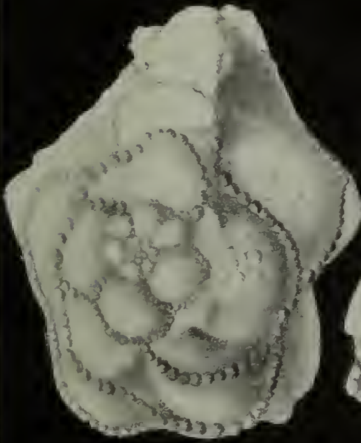

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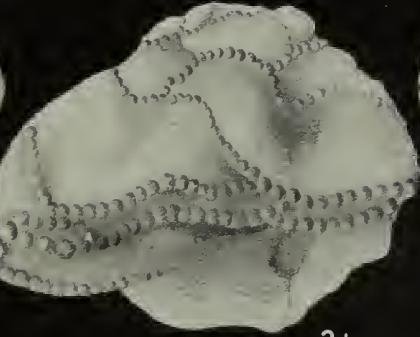

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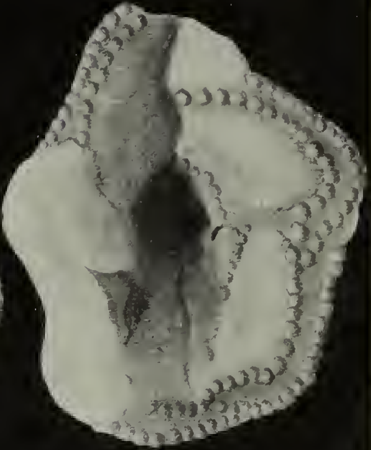

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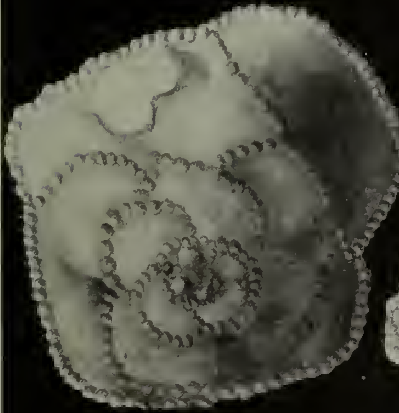

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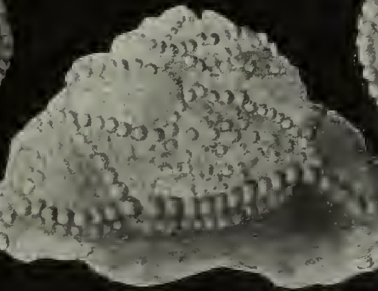

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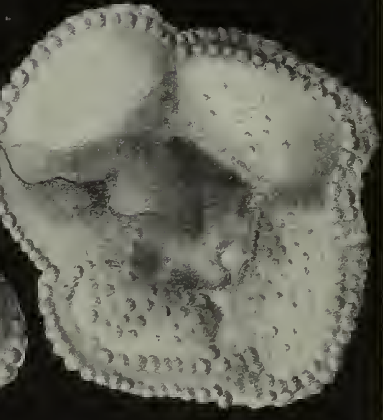


3c

PLATE 8

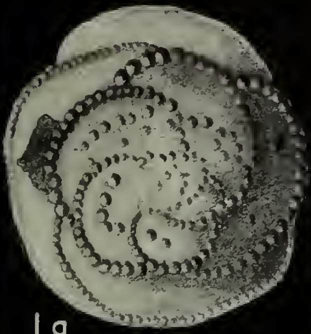
(All figures approximately × 76)
a, dorsal view ; b, d, side views ; c, ventral view

Figs. 1a–c. ***Globotruncana contusa patelliformis*** Gandolfi. Hypotype, from S.18, W. El-Sharawna section. P.45522

Figs. 2a–d. ***Globotruncana adamsi*** sp. nov. Holotype, from S.4, Abou Saboun section. P.45511

Figs. 3a–d. ***Globotruncana rosetta rosetta*** (Carsey). Hypotype, from S.16, W. El-Sharawna section. P.45552

Figs. 4a–d. ***Globotruncana stuarti stuarti*** (de Lapparent). Hypotype, from S.18, W. El-Sharawna section. P.45556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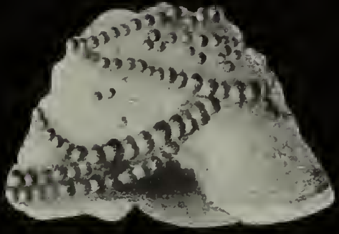
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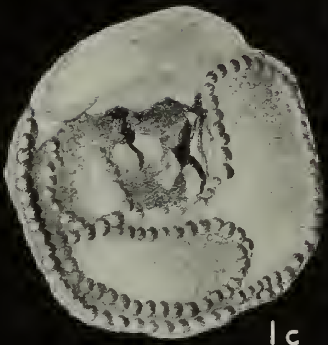
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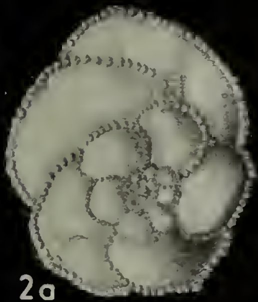
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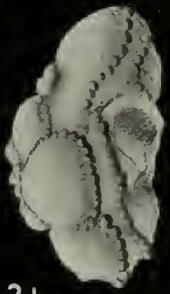
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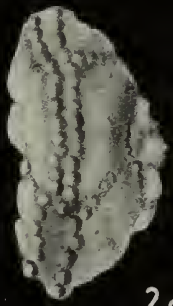
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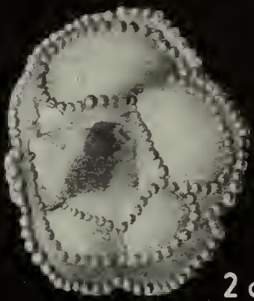
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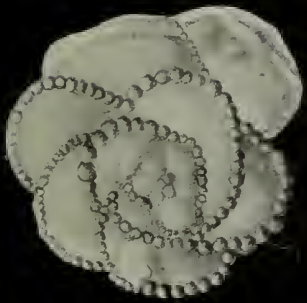
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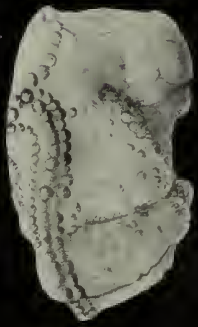
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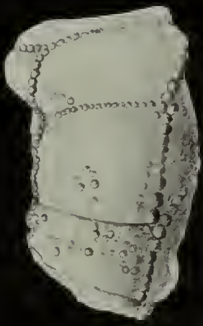
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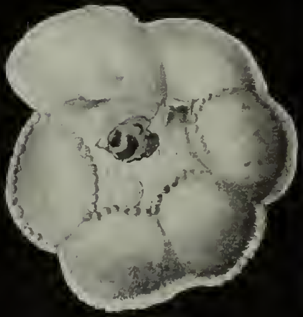
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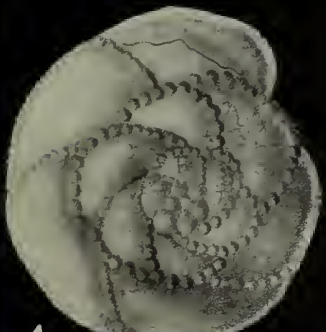
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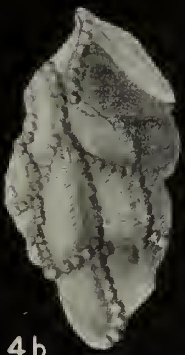
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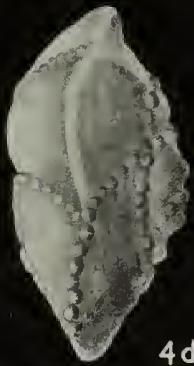
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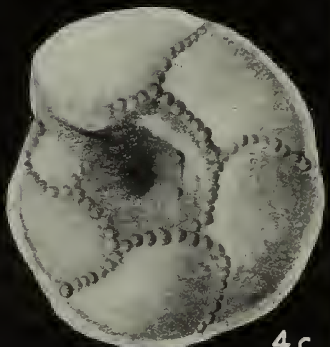
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PLATE 9

(All figures approximately × 76)
a, dorsal view ; b, d, side views ; c, ventral view

FIGS. 1a–d. ***Globotruncana stuarti stuarti*** (De Lapparent), transitional to ***Globotruncana stuarti parva*** Gandolfi. Hypotype, from S.18, W. El-Sharawna section. P.45556

FIGS. 2a–d. ***Globotruncana stuarti parva*** Gandolfi. Hypotype, from S.23, W. El-Sharawna section. P.45555

FIGS. 3a–d. ***Globotruncana stuarti stuartiformis*** Dalbiez. Hypotype, from S.18, W. El-Sharawna section. P.45558

FIGS. 4a–d. ***Globotruncana fareedi*** sp. nov. Holotype, from S.24, W. El-Sharawna section. P.455528

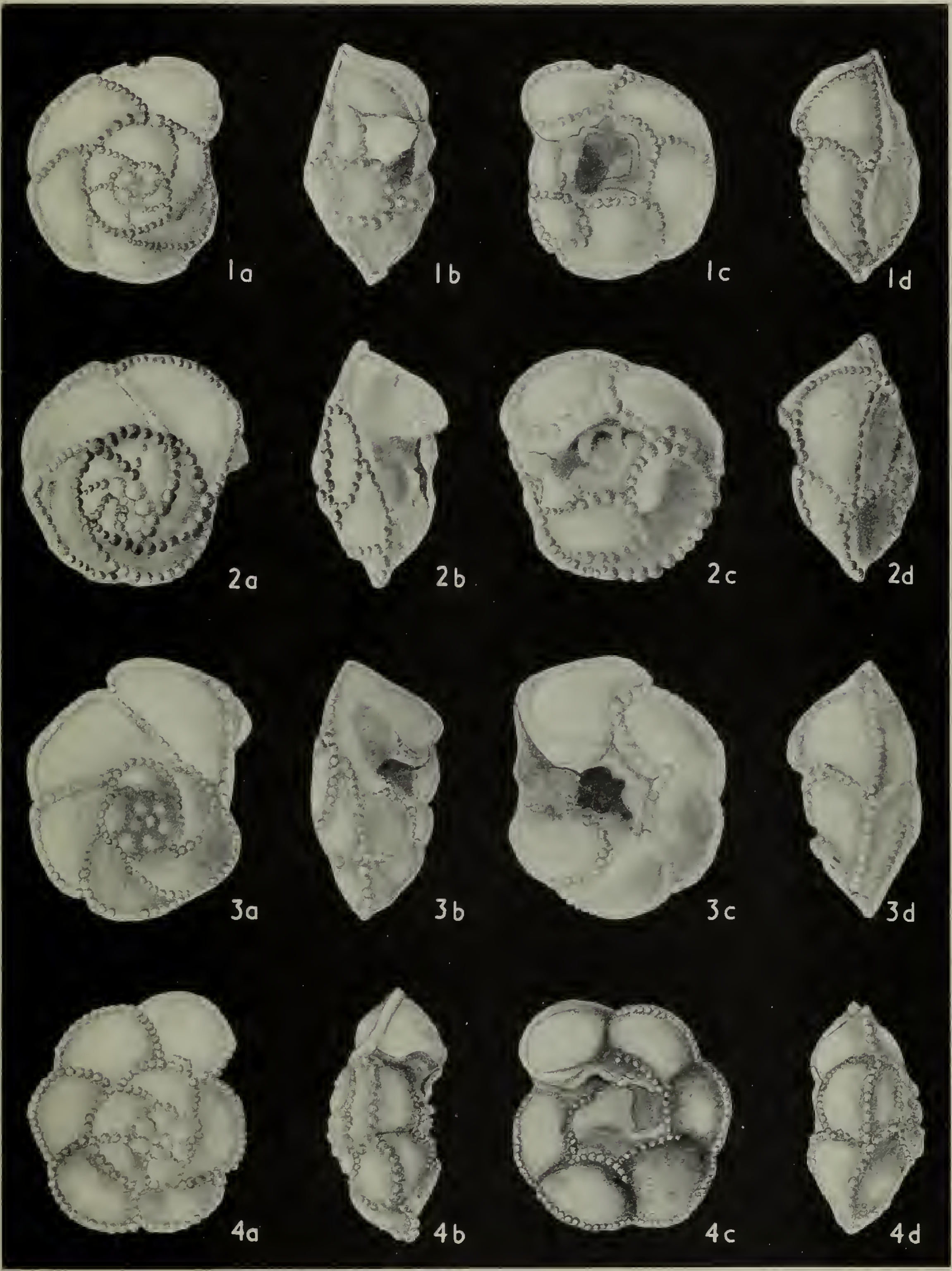
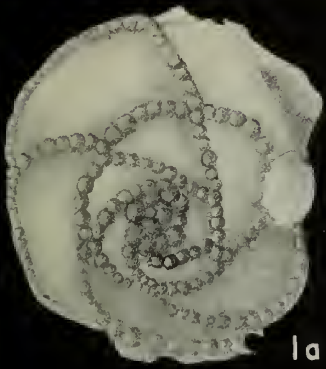

1a
1b
1c
1d
2a
2b
2c
2d
3a
3b
3c
3d
4a
4b
4c
4d

PLATE 10

(All figures approximately × 76)
a, dorsal view ; b, side view ; c, ventral view

Figs. 1a–c. Transitional form between ***Globotruncana stuarti subspinosa*** Pessagno and ***G. stuarti stuarti*** (de Lapparent), from S.16, W. El-Sharawna section. P.45557

Figs. 2a–3c. ***Globotruncana stuarti subspinosa*** Pessagno. Hypotypes, from S.18, W. El-Sharawna section. P.45559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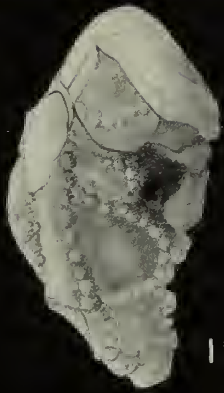
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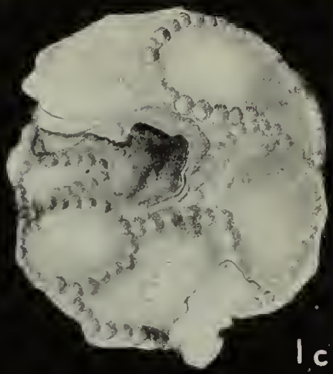
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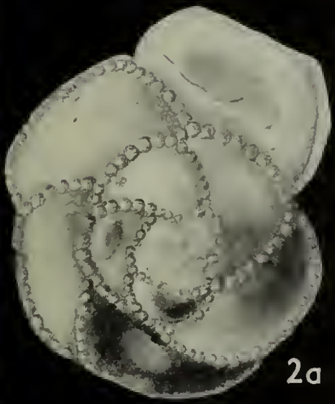
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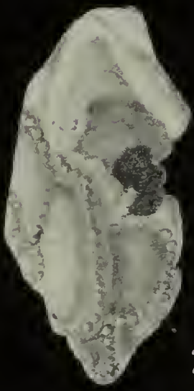
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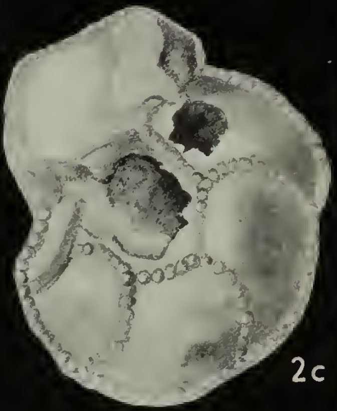
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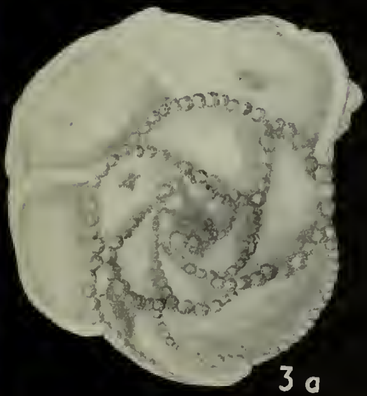
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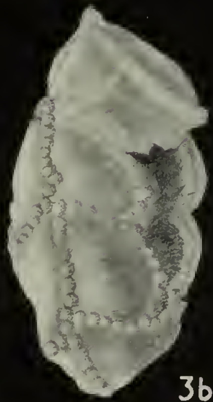
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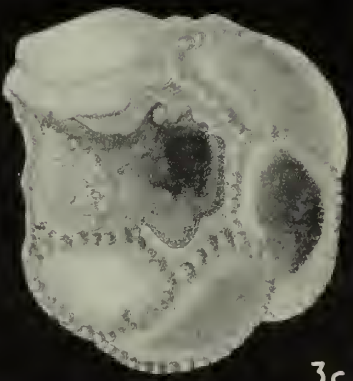

3c

PLATE 11

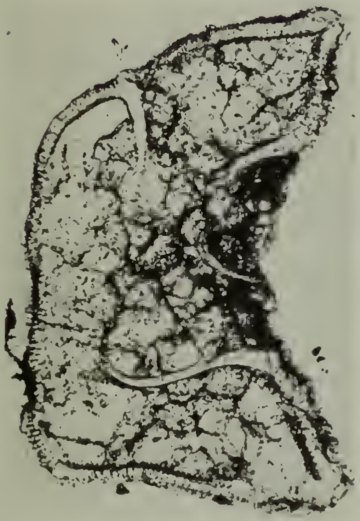
FIGS. 1a–b. ***Globotruncana contusa contusa*** (Cushman), from S.18, W. El-Sharawna section.

a—Axial section of hypotype, approximately × 120, plane polarized light. b—same, crossed nicols.

FIG. 2. ***Globotruncana lugeoni*** Tilev, from S.21, W. El-Sharawna section ; axial section of hypotype, approximately × 187, plane polarized light.

FIG. 3. ***Globotruncana gansseri gansseri*** Bolli, from S.18, W. El-Sharawna section ; axial section of hypotype, approximately × 440, plane polarized light.

FIG. 4. ***Globotruncana arabica*** sp. nov, from S.22, W. El-Sharawna section ; axial section of paratype, approximately × 154, plane polarized light.



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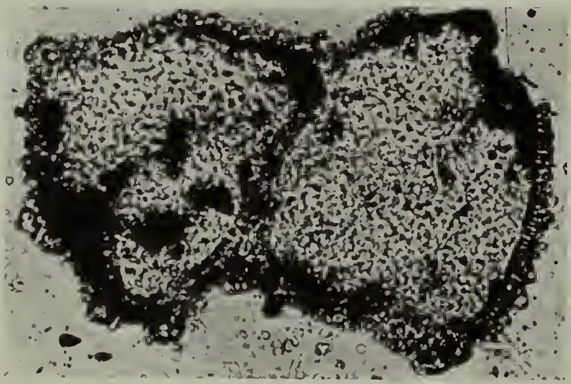
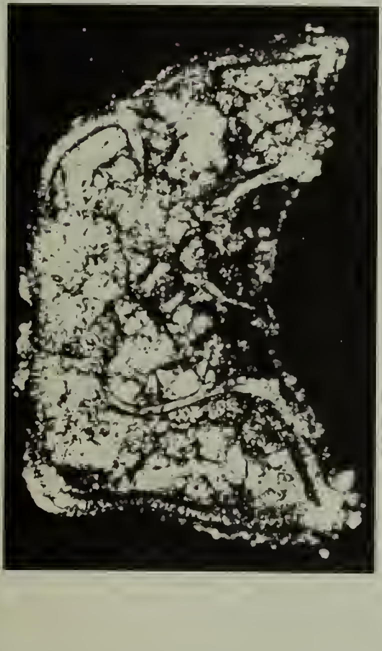


2

1b



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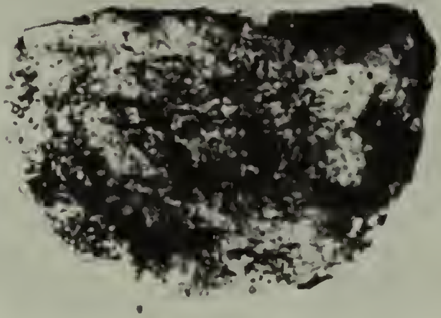

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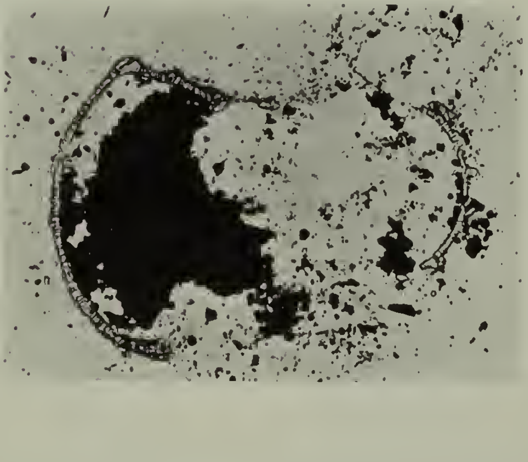


PLATE 12

(All figures approximately × 76)

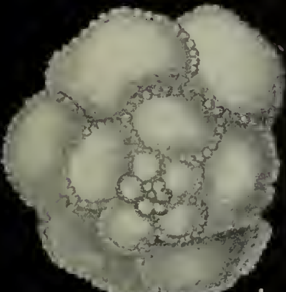
a, dorsal view ; b, d, side views ; c, ventral view

FIGS. 1a–d. ***Globotruncana esnehensis*** Nakkady & Osman. Hypotype, from S.17, W. El-Sharawna section. P.45527

FIGS. 2a–d. ***Globotruncana conica*** White. Hypotype, from S.16, Gebel Owaina section. P.45520

FIGS. 3a–d. ***Globotruncana sharawnaensis*** sp. nov. Holotype, from S.20, W. El-Sharawna section. P.45553

FIGS. 4a–d. ***Globotruncana orientalis*** sp. nov. Holotype, from S.18, W. El-Sharawna section. P.45549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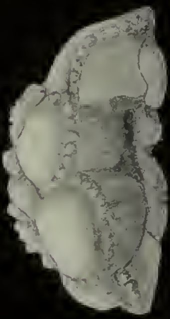
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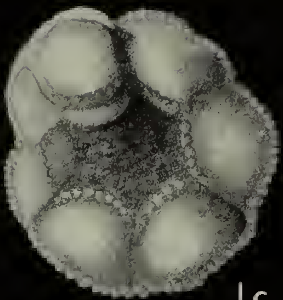
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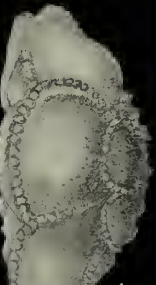
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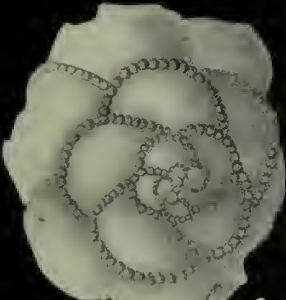
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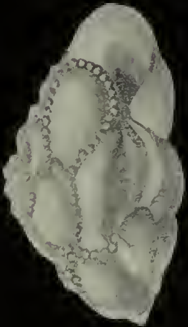
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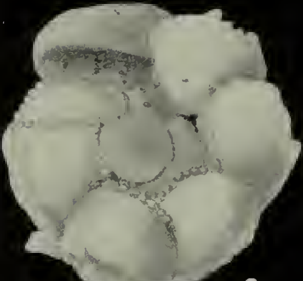
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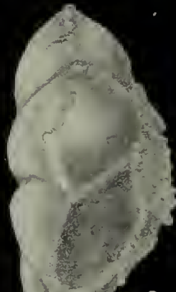
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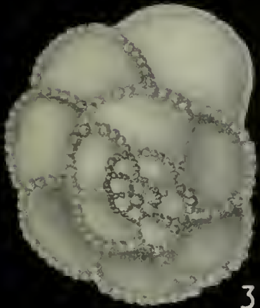
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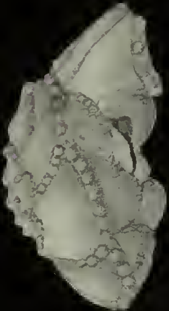
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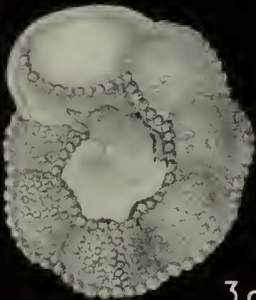
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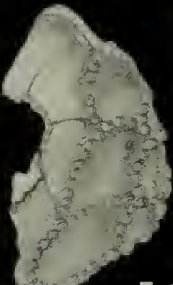
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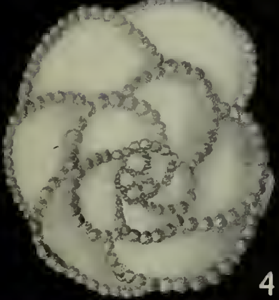
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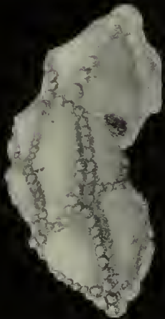
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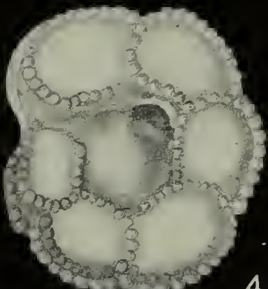
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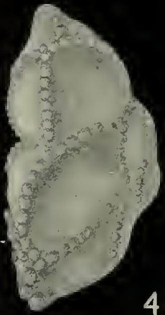

4d

PLATE 13

(All figures approximately × 76)

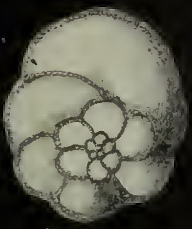
a, dorsal view ; b, side view ; c, ventral view

FIGS. 1a–c. ***Globotruncana fornicata globulocamerata*** subsp. nov. Paratype, from S.3, Abou Saboun section. P.45533

FIGS. 2a–c. ***Globotruncana fornicata manaurensis*** Gandolfi. Hypotype, from S.14, G.△ 314 section. P.45535

FIGS. 3a–4c. ***Globotruncana fornicata cesarensis*** Gandolfi. Hypotype 3, from S.16, W. El-Sharawna section, and 4 from S.4, G.△ 314 section. P.45530

FIGS. 5a–6. ***Globotruncana fornicata fornicata*** Plummer. Hypotype 5, from S.14, G.△ 314 section, and 6, from S.3, Abou Saboun section. P.45531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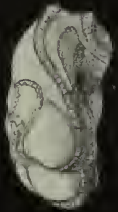
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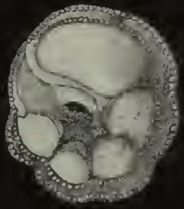
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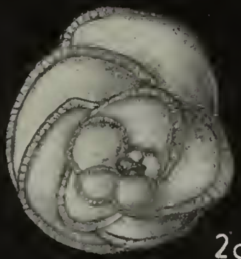
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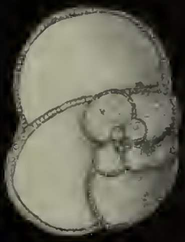
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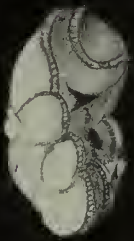
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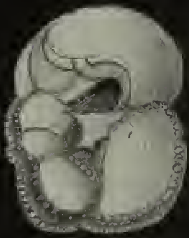
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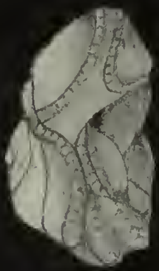
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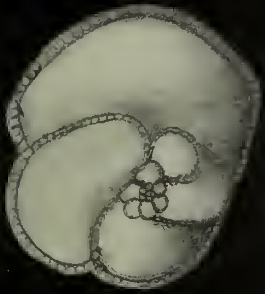
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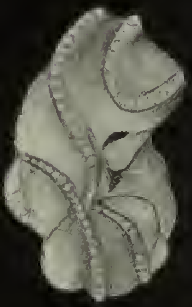
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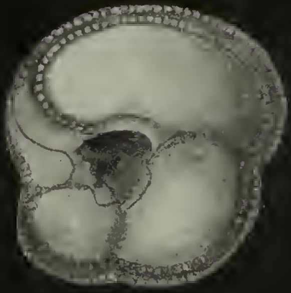
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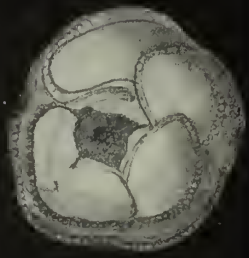
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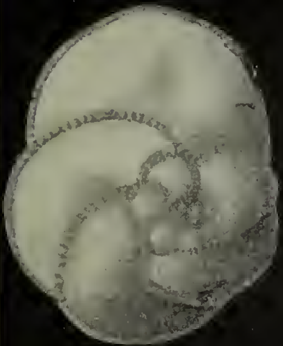
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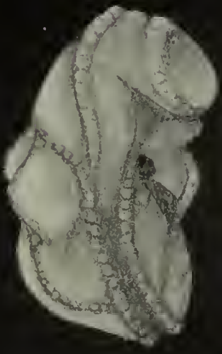
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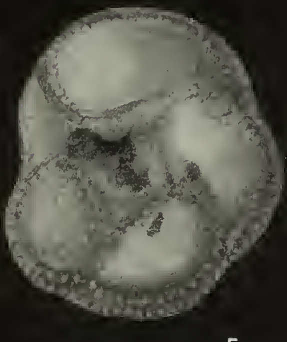
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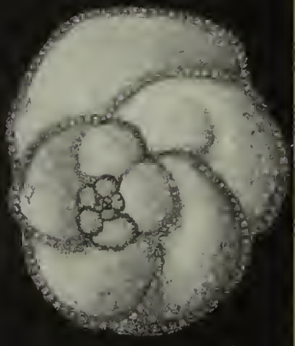

6

PLATE 14

(All figures approximately × 76)

a, dorsal view ; b, d, side views ; c, ventral view

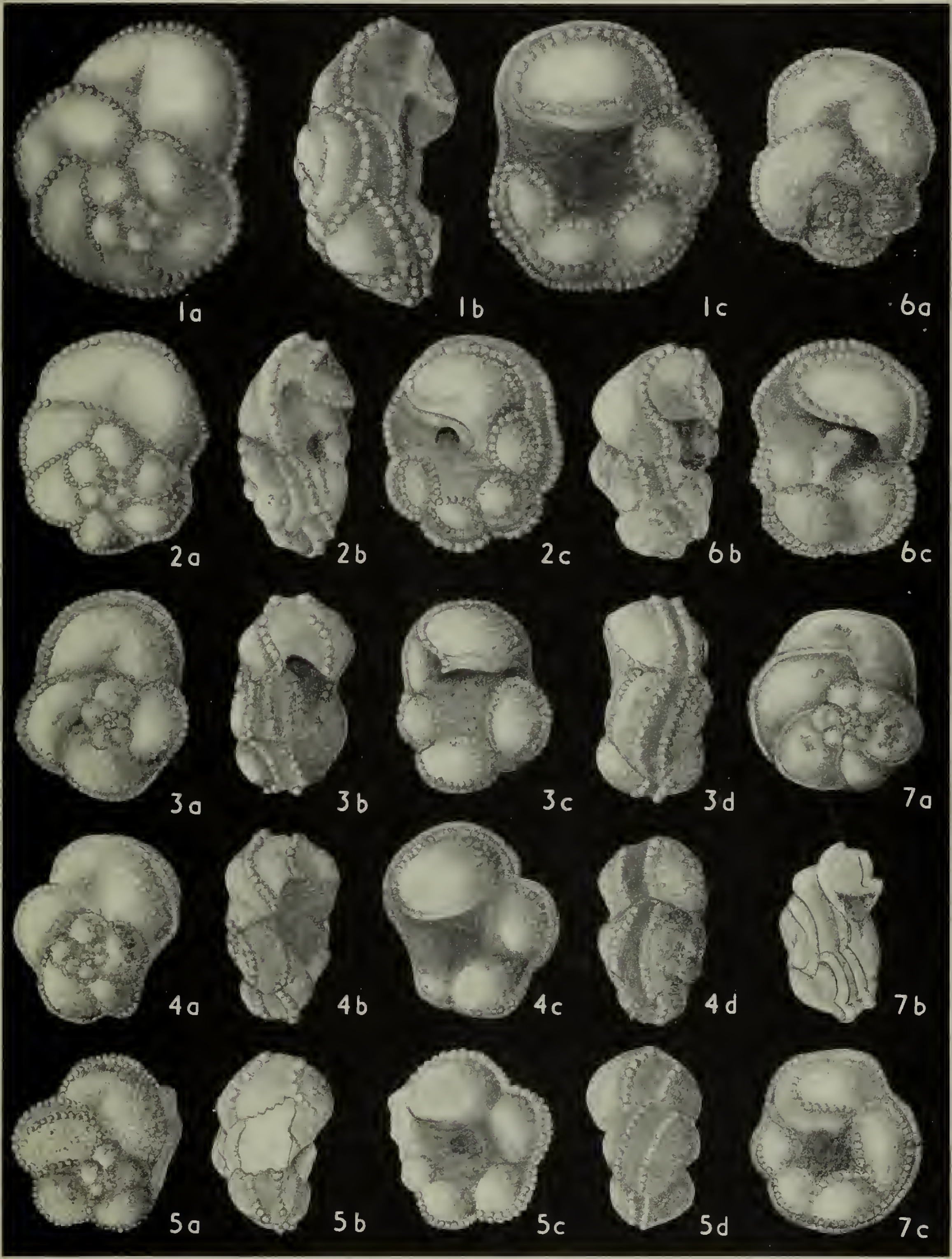
Figs. 1a–c. Transitional stage between ***Globotruncana fornicata fornicata*** Plummer and ***Globotruncana fornicata globulocamerata*** subsp. nov. from S.4, Abou Saboun section. P.45534

Figs. 2a–c. ***Globotruncana fornicata globulocamerata*** subsp. nov. Holotype, from S.4, Abou Saboun section. P.45532

Figs. 3a–5d. ***Globotruncana fornicata ackermanni*** Gandolfi. Hypotype, from S.4, Abou Saboun section. P.45529

Figs. 6a–c. ***Globotruncana fornicata cesarensis*** Gandolfi. Hypotype, from S.4, Abou Saboun section. P.45530

Figs. 7a–c. Transitional stage between ***Globotruncana fornicata manaurensis*** Gandolfi and ***Globotruncana tricarinata tricarinata*** (Quereau). P.45536


1a
1b
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2c
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3b
3c
3d
7a
4a
4b
4c
4d
7b
5a
5b
5c
5d
7c

PLATE 15

(All figures approximately × 76, except 1a–c, × 116)
a, dorsal view ; b, side view ; c, ventral view

FIGS. 1a–c, 2. ***Globigerina kozlowskii*** Brotzen & Pozaryska. Hypotype, from S.7, Gebel El-Kilabiya section. P.45579

FIGS. 3a–c. ***Globigerina daubjergensis*** Brönnimann. Hypotype, from S.7, Gebel El-Kilabiya section. P.45575

FIGS. 4a–c. ***Globigerina triloculinoides*** *parva* subsp. nov. Holotype, from S.53, Gebel Owaina section. P.45587

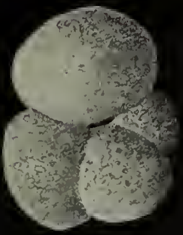
FIGS. 5a–c. ***Globigerina haynesi*** sp. nov. Holotype, from S.64, Gebel Owaina section. P.45576

FIGS. 6a–c. ***Globigerina nodosa*** sp. nov. Holotype, from S.49, Gebel Owaina section. P.45581

FIGS. 7a–c. ***Globigerina triloculinoides*** Plummer. Hypotype, from S.38, Gebel Owaina section. P.45586

FIGS. 8a–c. ***Globigerina inaequispira*** Subbotina. Hypotype, from S.49, Gebel Owaina section. P.45578

PLATE 15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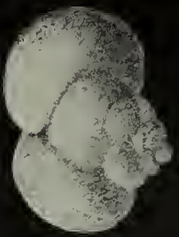
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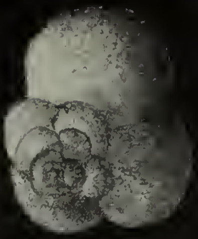
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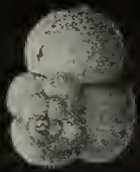
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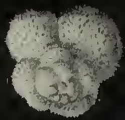
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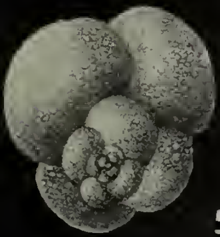
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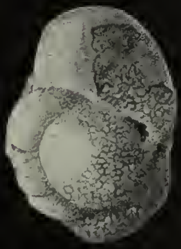
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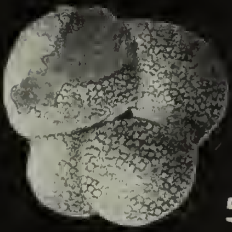
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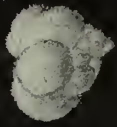
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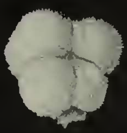
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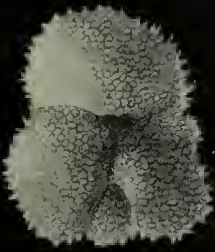
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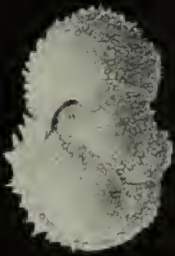
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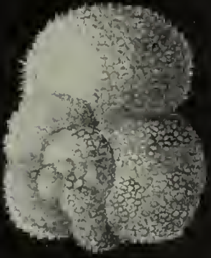
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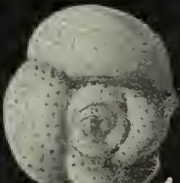
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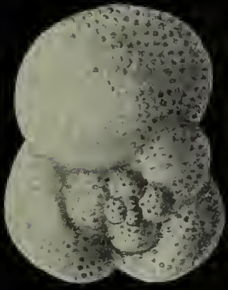
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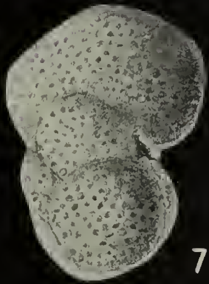
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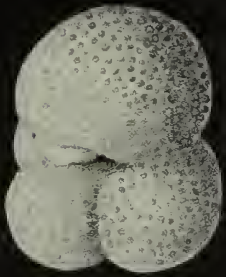
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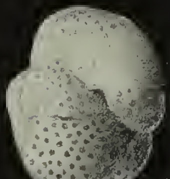
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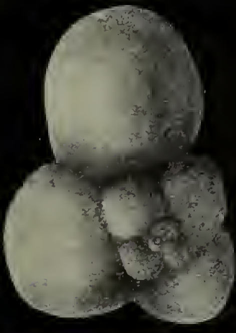
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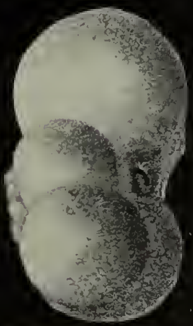
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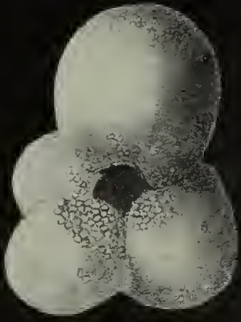
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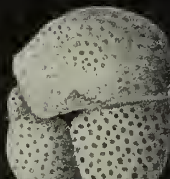

4c

PLATE 16

(All figures approximately × 78)
a, dorsal view ; b, d, side views ; c, ventral view

FIGS. 1a–d. ***Globigerina stonei*** Weiss. Hypotype, from S.68, Gebel Owaina section. P.45585

FIGS. 2a–c. ***Globigerina spiralis*** Bolli. Hypotype, from S.53, Gebel Owaina section. P.45584

FIGS. 3a–d. ***Globigerina velascoensis*** Cushman. Hypotype, from S.51, Gebel Owaina section. P.45589

FIGS. 4a–c. ***Globigerina chascanona*** Loeblich & Tappan. Hypotype, from S.64, Gebel Owaina section. P.45574

FIGS. 5a–c. ***Globigerina mckannai*** White. Hypotype, from S.51, Gebel Owaina section. P.45580

FIGS. 6a–c. ***Globigerina alanwoodi*** sp. nov. Holotype, from S.43, Gebel Owaina section. P.45567

PLATE 16

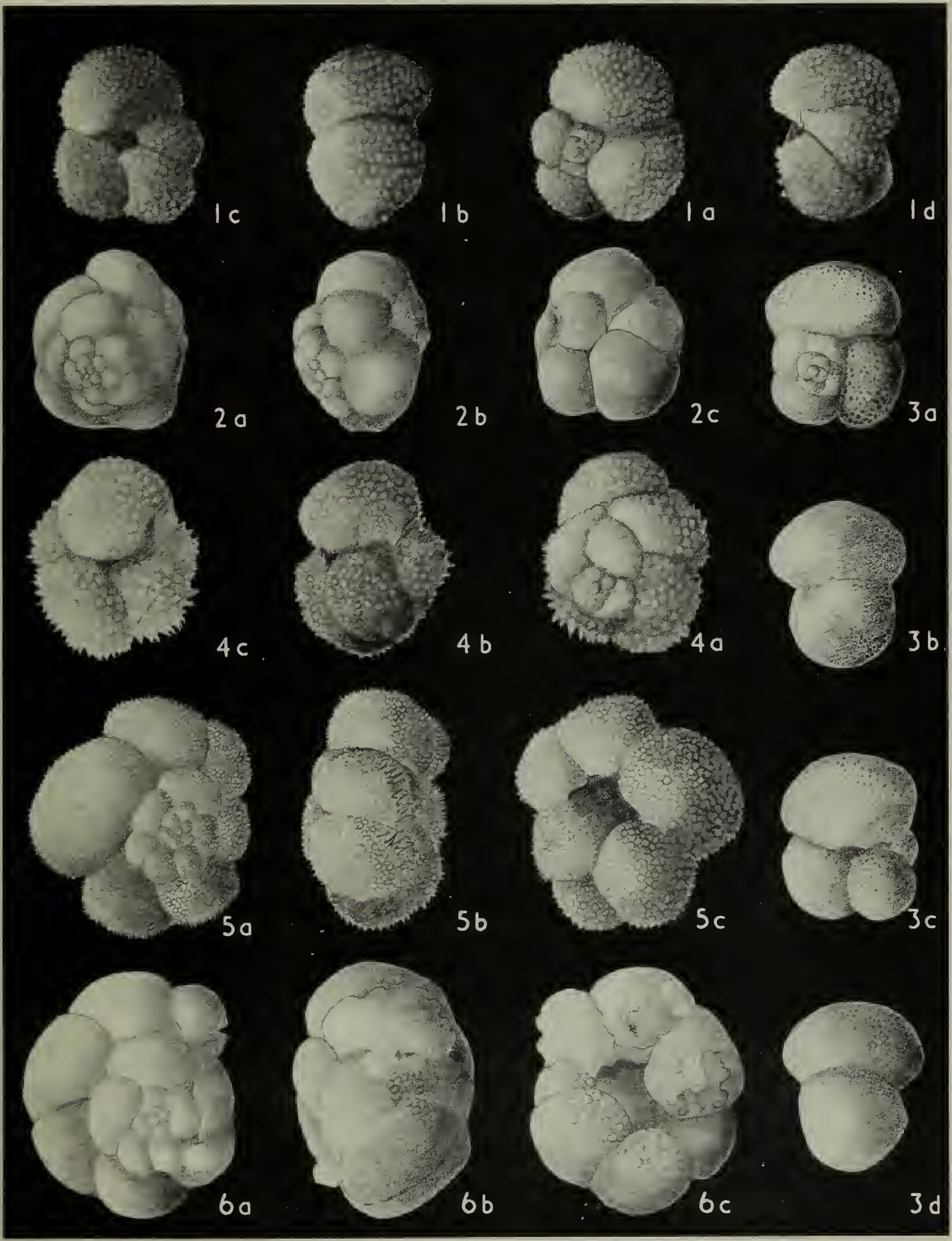


PLATE 17

(All figures approximately × 78)

a, dorsal view ; b, side view ; c, ventral view

FIGS. 1a–3c. ***Globorotalia compressa*** (Plummer). Hypotypes, from S.31, S.30, Gebel Owaina section, and S.7, Gebel El-Kilabiya section respectively. P.45601–03

FIGS. 4a–c. ***Globorotalia kilabiyaensis*** sp. nov. Holotype, from S.7, Gebel El-Kilabiya section. P.45613

FIGS. 5a–c. ***Globorotalia ehrenbergi*** Bolli. Hypotype, from S.37, Gebel Owaina section. P.45605

FIGS. 6a–c. ***Globorotalia imitata*** Subbotina. Hypotype, from S.7, Gebel El-Kilabiya section. P.45611

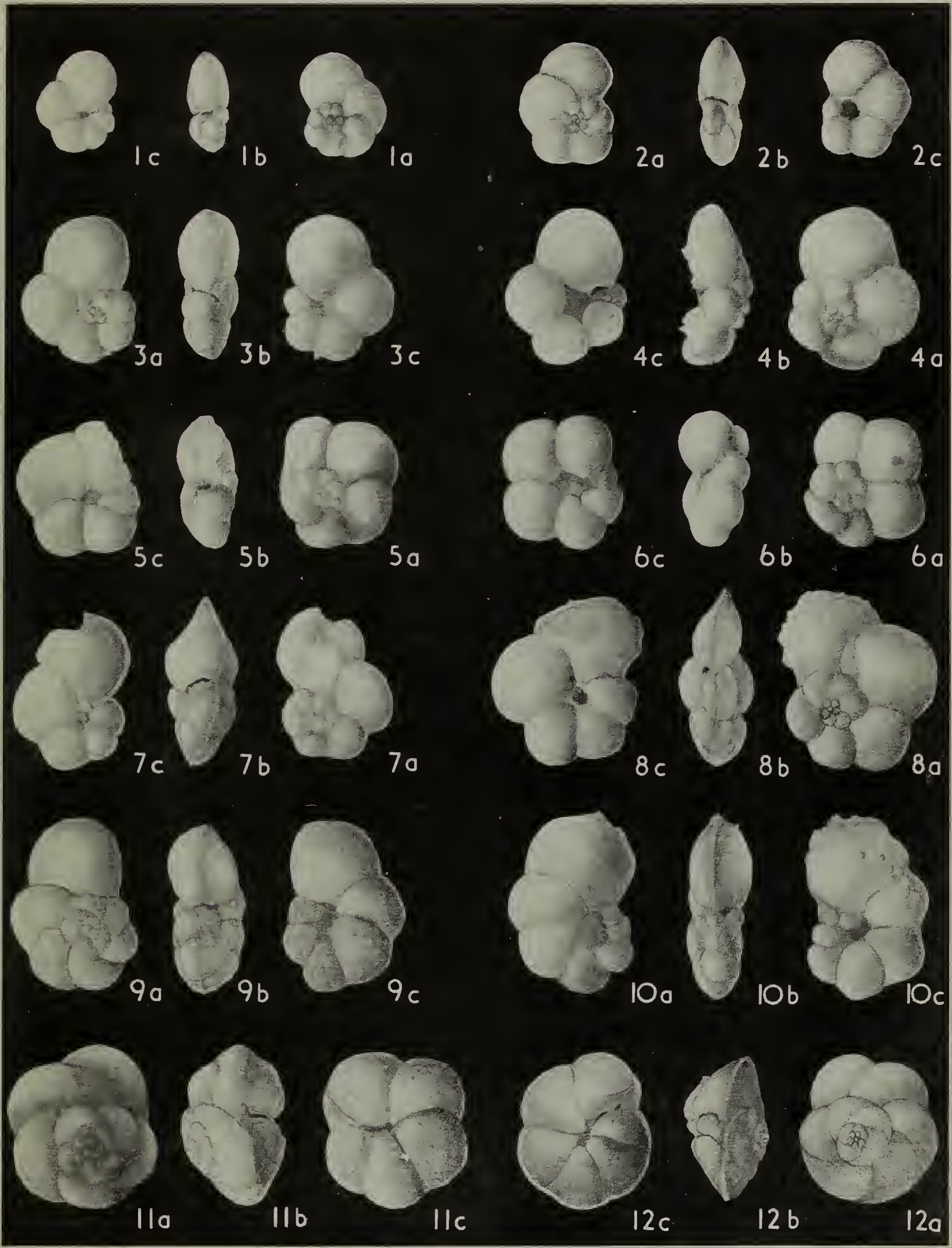
FIGS. 7a–8c. ***Globorotalia pseudomenardii*** Bolli. Hypotypes from S.39, Gebel Owaina section. P.45622

FIGS. 9a–c. ***Globorotalia emilei*** sp. nov. Holotype, from S.33, Gebel Owaina section. P.45606

FIGS. 10a–c. ***Globorotalia troelseni*** Loeblich & Tappan. Hypotype, from S.68, Gebel Owaina section. P.45633

FIGS. 11a–c. ***Globorotalia pusilla pusilla*** Bolli. Hypotype, from S.37, Gebel Owaina section. P.45626

FIGS. 12a–c. ***Globorotalia pusilla laevigata*** Bolli. Hypotype, from S.48, Gebel Owaina section. P.45623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9b
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10a
10b
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11a
11b
11c
12c
12b
12a

PLATE 18

(All figures approximately × 76)

a, dorsal view ; b, side view ; c, ventral view

FIGS. 1a–c. ***Globorotalia uncinata uncinata*** Bolli. Hypotype, from S.34, Gebel Owaina section. P.45636

FIGS. 2a–c. ***Globorotalia tribulosa*** Loeblich & Tappan. Hypotype, from S.32, Gebel Owaina section. P.45630

FIGS. 3a–c. ***Globorotalia pseudobulloides*** (Plummer). Hypotype, from S.38, Gebel Owaina section showing a slightly extraumbilical aperture. P.45621

FIGS. 4a–c. ***Globorotalia quadrata*** White. Hypotype, from S.7, Gebel El-Kilabiya section, showing a very slightly extraumbilical aperture. P.45627

FIGS. 5a–c. Transitional stage between ***Globorotalia trinidadensis*** Bolli and ***Globorotalia uncinata uncinata*** Bolli. P.45632

FIGS. 6a–c. ***Globigerina arabica*** sp. nov. Holotype, from S.30, Gebel Owaina section. P.45570.

FIGS. 7a–c. ***Globorotalia trinidadensis*** Bolli. Hypotype, from S.7, Gebel El-Kilabiya section. P.45631

PLATE 18

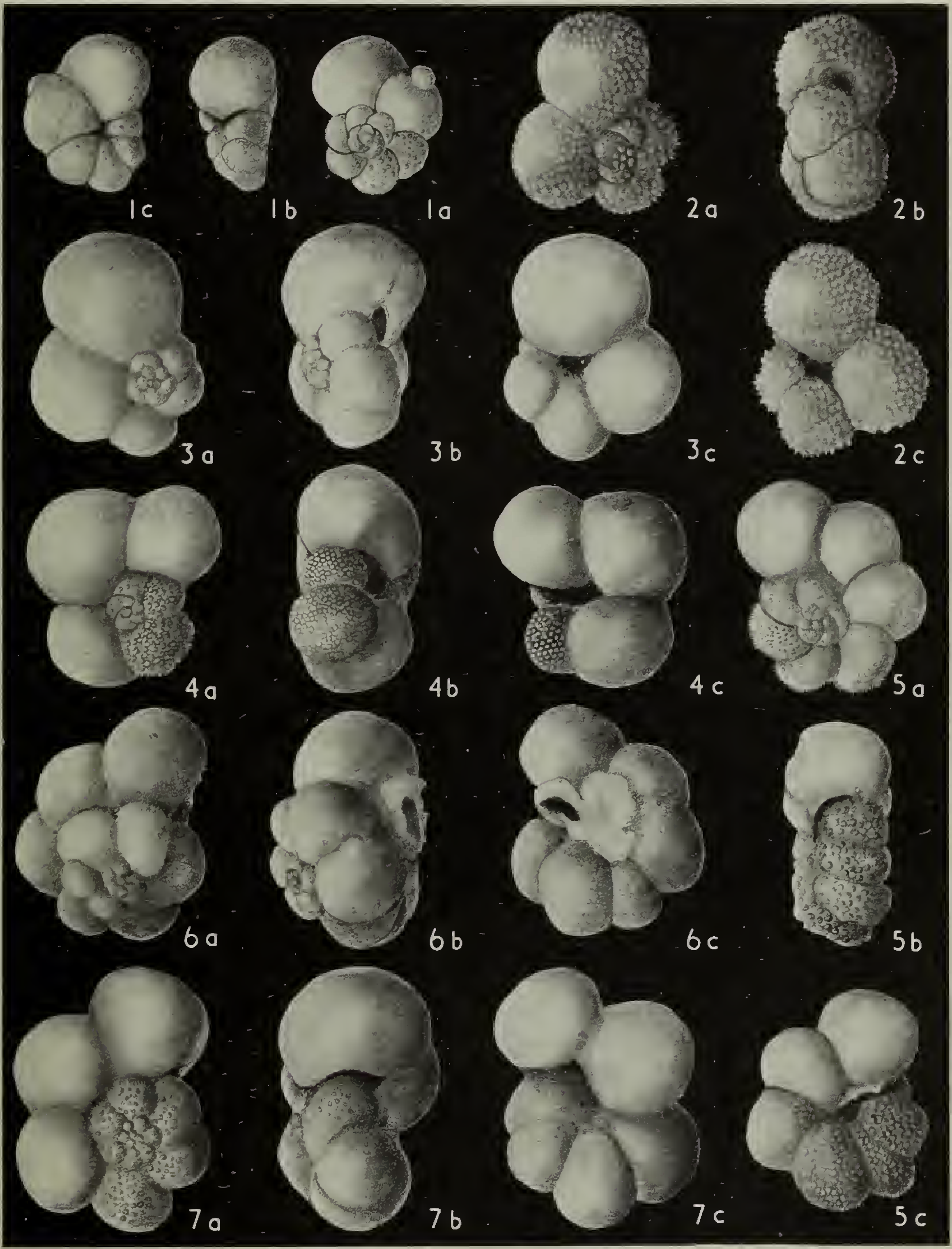


PLATE 19

(All figures approximately × 76)

a, dorsal view ; b, d, side views ; c, ventral view

FIGS. 1a–d. ***Globorotalia uncinata carinata*** subsp. nov. Holotype, from S.36, Gebel Owaina section. P.45634

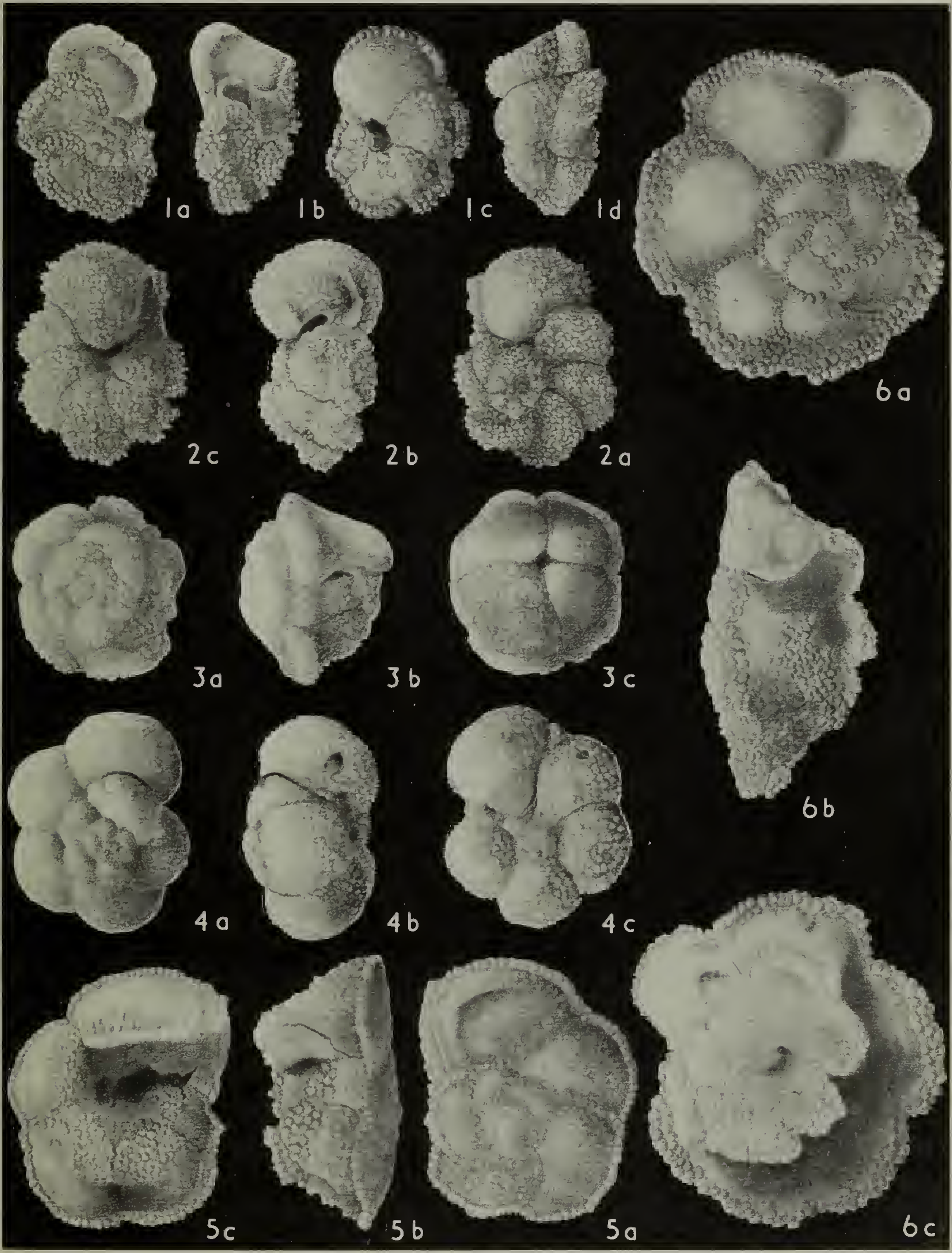
FIGS. 2a–c. ***Globorotalia uncinata uncinata*** Bolli. Hypotype, from S.35, Gebel Owaina section. P.45637

FIGS. 3a–c. ***Globorotalia pusilla mediterranica*** subsp. nov. Holotype, from S.37, Gebel Owaina section. P.45624

FIGS. 4a–c. ***Globorotalia faragi*** sp. nov. Holotype, from S.34, Gebel Owaina section. P.45608

FIGS. 5a–c. ***Globorotalia acuta*** Toulmin. Hypotype, from S.40, Gebel Owaina section. P.45591

FIGS. 6a–c. ***Globorotalia velascoensis caucasica*** (Glaessner). Hypotype, from S.41, Gebel Owaina section. P.45638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6b
4a
4b
4c
5c
5b
5a
6c

PLATE 20

(All figures approximately × 76)
a, dorsal view ; b, d, side views ; c, ventral view

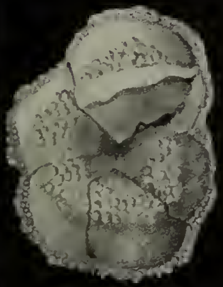
FIGS. 1a–d. ***Globorotalia acuta*** Toulmin. Hypotype, from S.40, Gebel Owaina section. P.45590

FIGS. 2a–d. ***Globorotalia occlusa*** Loeblich & Tappan. Hypotype, from S.40, Gebel Owaina section. P.45618

FIGS. 3a–d. ***Globorotalia velascoensis velascoensis*** (Cushman). Hypotype, from S.41, Gebel Owaina section. P.45640

FIGS. 4a–d. ***Globorotalia velascoensis parva*** Rey. Hypotype, from S.41, Gebel Owaina section. P.45639

PLATE 20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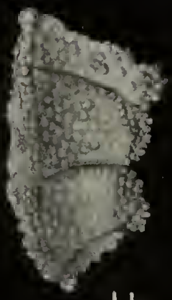
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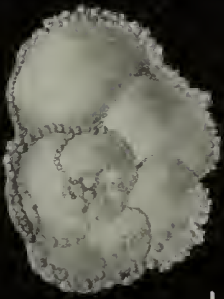
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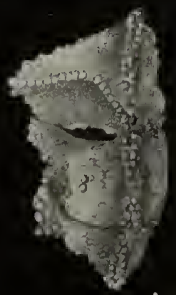
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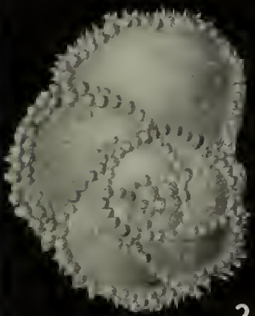
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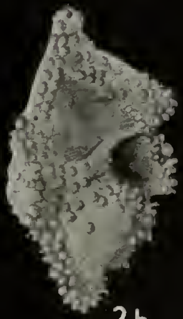
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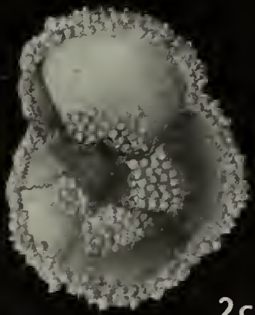
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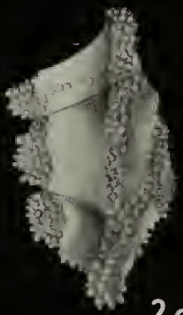
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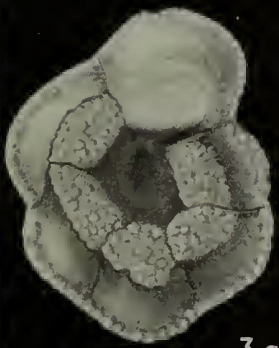
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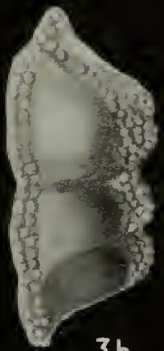
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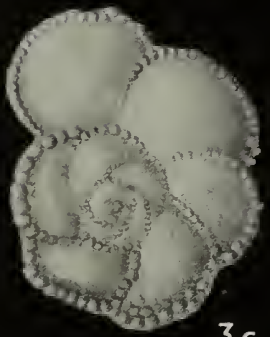
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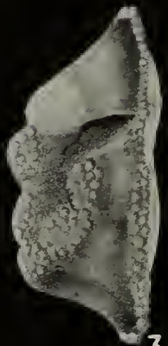
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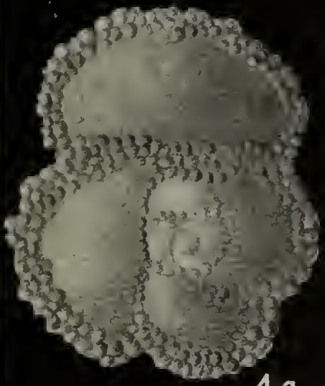
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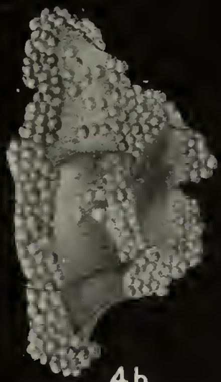
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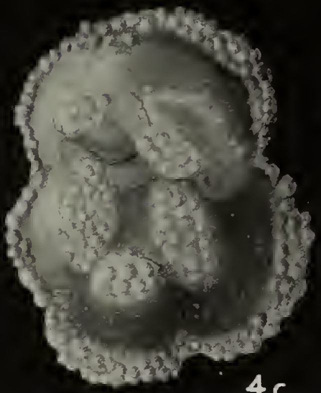
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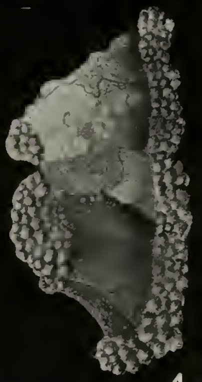

4d

PLATE 21

(All figures approximately × 76)

a, dorsal view; b, side view ; c, ventral view

FIGS. 1a–c. ***Globorotalia apanthesma*** Loeblich & Tappan. Hypotype, from S.40, Gebel Owaina section. P.45596

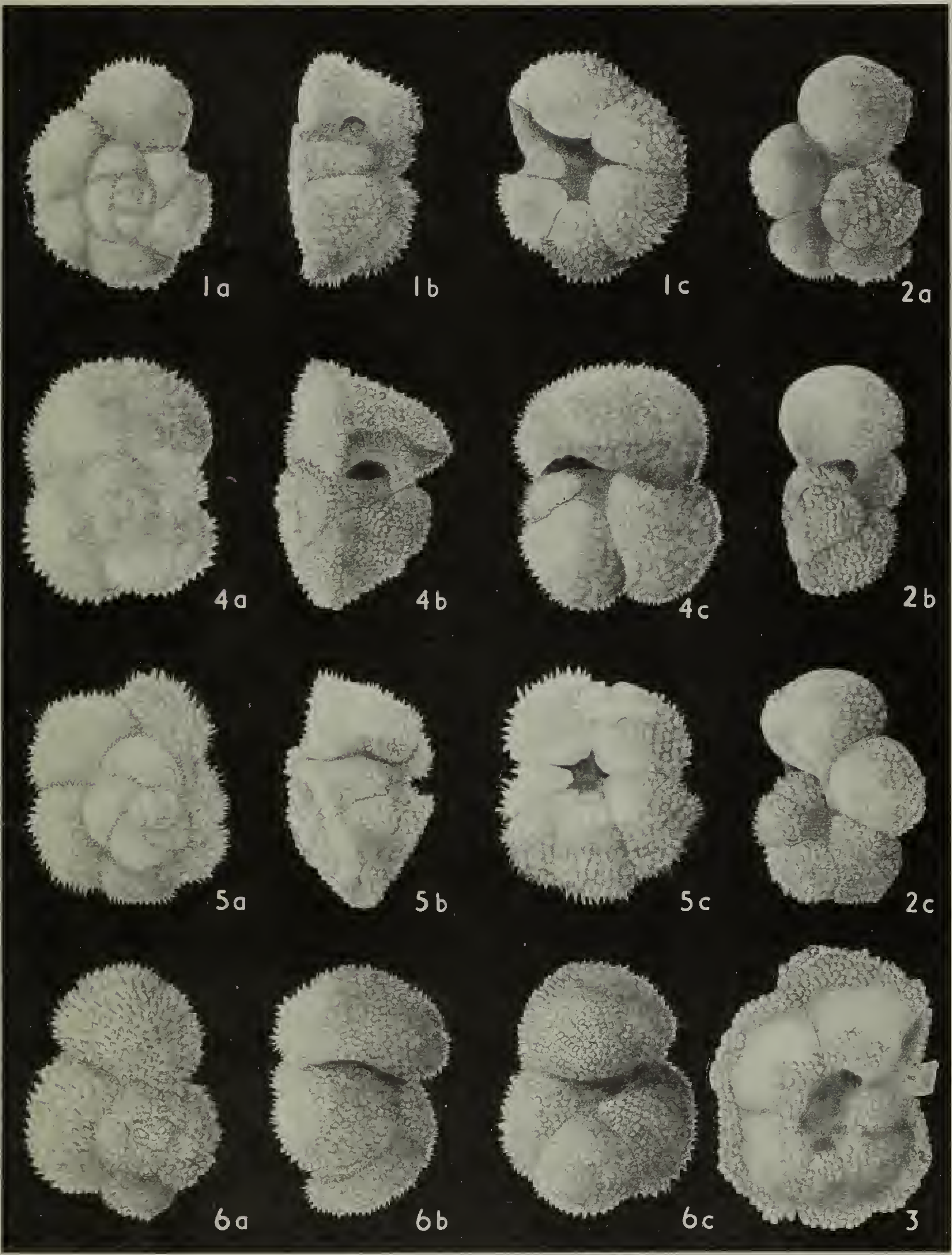
FIGS. 2a–c. ***Globorotalia perclara*** Loeblich & Tappan. Hypotype, from S.35, Gebel Owaina section. P.45620

FIG. 3. ***Globorotalia velascoensis velascoensis*** (Cushman). Ventral view of Hypotype, from S.37, Gebel Owaina section, showing a distinctly protruding ventral side and a relatively narrow umbilicus. P.45641

FIGS. 4a–c. ***Globorotalia aequa*** Cushman & Renz. Hypotype from S.55, Gebel Owaina section. P.45592

FIGS. 5a–c. ***Globorotalia hispidicidaris*** Loeblich & Tappan. Hypotype, from S.55, Gebel Owaina section. P.45610

FIGS. 6a–c. ***Globorotalia esnaensis*** (Le Roy). Hypotype, from S.49, Gebel Owaina section. P.45607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4c
2b
5a
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5c
2c
6a
6b
6c
3

PLATE 22

(All figures approximately × 76)

a, dorsal view ; b, d, side views ; c, ventral view

FIGS. 1a–c. ***Globorotalia angulata angulata*** (White). Hypotype, from S.35, Gebel Owaina section. P.45595

FIGS. 2a–c. ***Globorotalia angulata abundocamerata*** Bolli. Hypotype, from S.39, Gebel Owaina section. P.45594

FIGS. 3a–c. ***Globorotalia*** cf. ***convexa*** Subbotina. Hypotype, from S.37, Gebel Owaina section. P.45604

FIGS. 4a–c. ***Globorotalia occlusa*** Loeblich & Tappan. Hypotype, from S.51, Gebel Owaina section. P.45619

FIGS. 5a–6d. ***Globorotalia bollii*** sp. nov. Figs. 5a–d, holotype and figs. 6a–d, paratype from S.68, Gebel Owaina section. P.45599, P.45600

PLATE 22

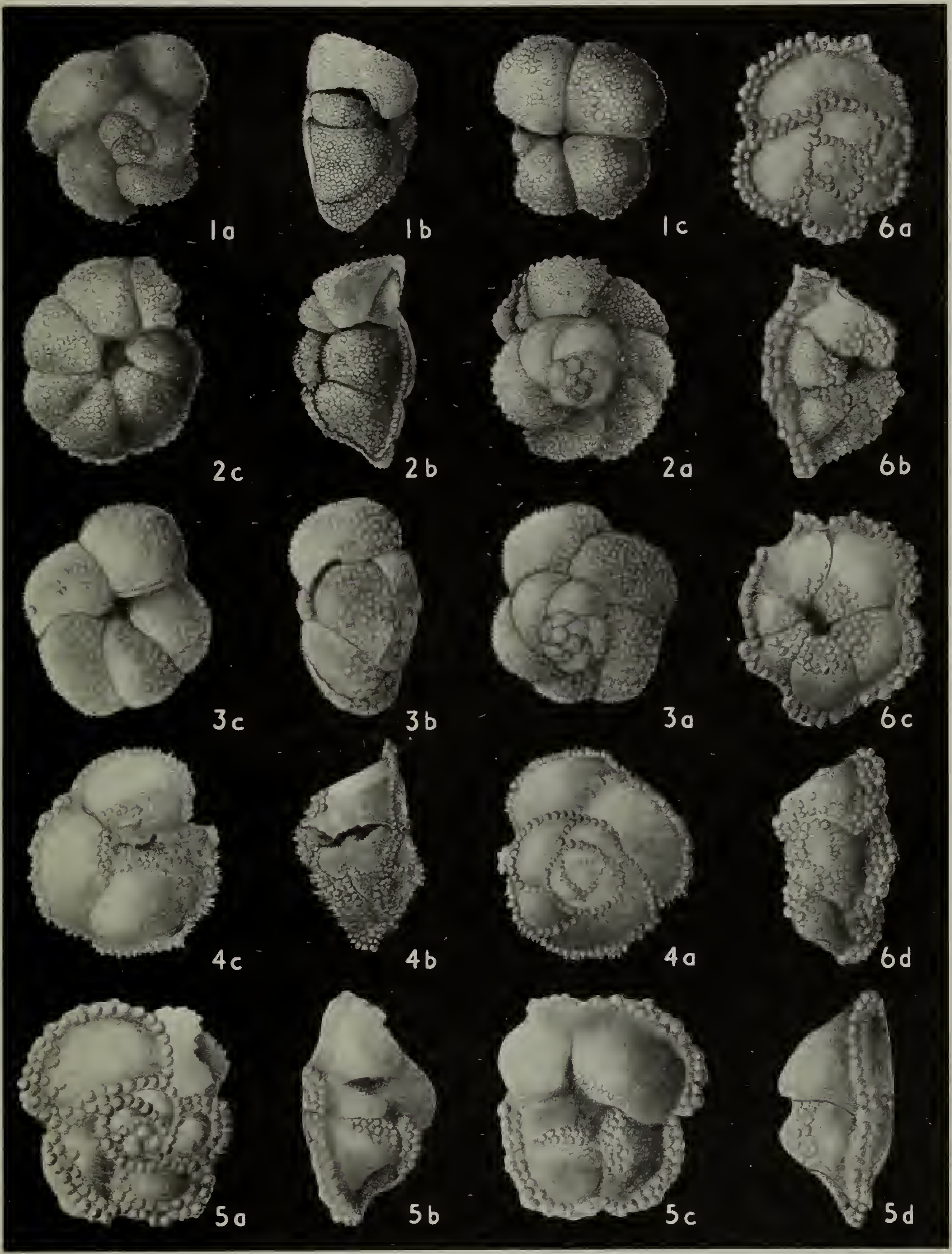


PLATE 23

(All figures approximately × 76)
a, dorsal view ; b, d, side views ; c, ventral view

FIGS. 1a–c. ***Globorotalia loeblichi*** sp. nov. Holotype, from S.68, Gebel Owaina section. P.45615

FIGS. 2a–c. ***Globorotalia woodi*** sp. nov. Holotype from S.40, Gebel Owaina section. P.45616

FIGS. 3a–c. ***Globorotalia whitei*** Weiss. Hypotype, from S.55, Gebel Owaina section. P.45642

FIGS. 4a–c. ***Globorotalia africana*** sp. nov. Holotype, from S.50, Gebel Owaina section. P.45593

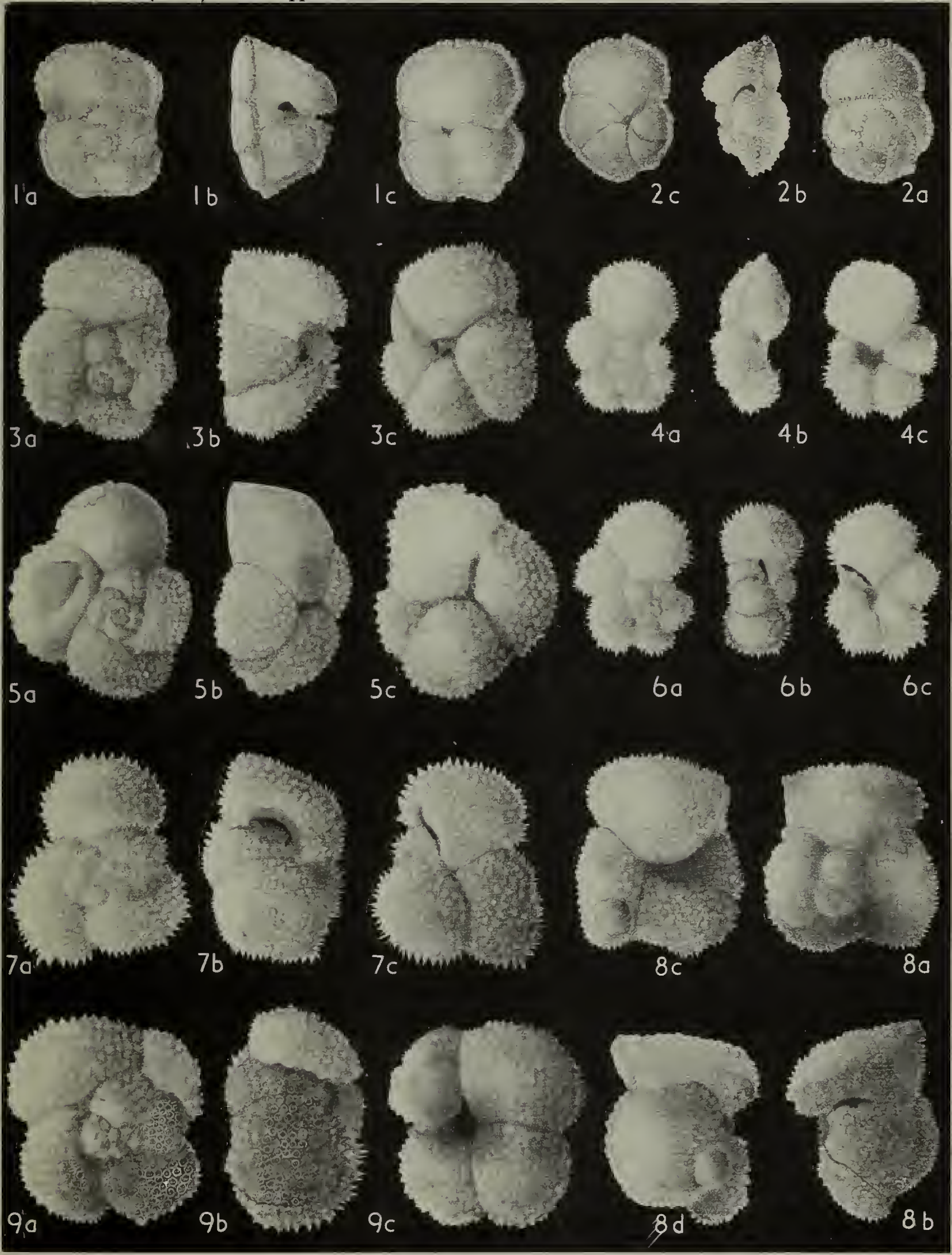
FIGS. 5a–c. ***Globorotalia wilcoxensis*** Cushman & Ponton. Holotype, from S.64, Gebel Owaina section. P.45643

FIGS. 6a–c. ***Globorotalia sibaîyaensis*** sp. nov. Holotype, from S.50, Gebel Owaina section. P.45628

FIGS. 7a–c. ***Globorotalia berggreni*** sp. nov. Holotype, from S.51, Gebel Owaina section. P.45597

FIGS. 8a–d. ***Globorotalia*** sp., from S.35, Gebel Owaina section. P.45644

FIGS. 9a–c. ***Globorotalia irrorata*** Loeblich & Tappan. Hypotype, from S.51, Gebel Owaina section. P.45612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